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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

TOPICAL REPORT NO. 105

YUKON RIVER DRAINAGE BASIN

DAM SITE INVESTIGATION

SITE No. 27

HOOLE CANYON DAM SITE

(Map and Preliminary Report)

BY

E. B. OWEN

OTTAWA

1965

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HOOLE CANYON DAM SITE

General Description

The examination of Hoole Canyon as a potential dam site is part of an investigation by the Water Resources Branch of the Department of Northern Affairs and National Resources of the hydro-electric power potential in the Yukon River drainage basin.

The proposed dam site is located on Pelly River about 24 miles upstream from the community of Ross River in Yukon Territory. It is included on National Topographic Series sheet No. 105F (Quiet Lake), scale 1:250,000, and on Royal Canadian Air Force aerial photograph A.12177-349 flown in 1949. The scale of the photograph is approximately 1 inch to 3,200 feet. Most of the reservoir area is on sheet No. 105G (Finlayson Lake).

A dam constructed at Hoole Canyon would be relatively important in the development of power on Pelly River. It is the furthest upstream of 4 sites proposed for the river and could be utilized not only to produce power but also to provide storage for the downstream projects.

The proposed site can be reached from Ross River by shallow draft boats which, except in periods of extremely low water, can ascend the river to the downstream end of the canyon. The site can also be reached by walking from the Ross River-Watson Lake road which, at a point about a mile west of Horton Creek, is about 2 miles from the canyon.

Pelly River which is one of the larger Canadian tributaries of Yukon River drains an area of about 25,000 square miles in the southern part of the interior of Yukon Territory[1]. It originates in Selwyn Mountains close to the boundary between the Northwest Territories and Yukon Territory. It flows southwest

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[1] Johnston, J.R.: A Reconnaissance of Pelly River between Macmillan River and Hoole Canyon, Yukon, Geol. Surv. Can., Mem. 200, 1936.

across Pelly Plateau until it reaches Pelly Mountains and then follows along the northeast flank of these mountains to their northwest extremity where it curves to the west to join Yukon River at Fort Selkirk. The valley of Pelly River where it parallels the mountains is a distinct topographic feature which continues as a trench-like depression for several hundred miles across the southern part of Yukon Territory. It is known as Tintina Trench[1].

During the last glaciation the Trench was filled with ice which moved down grade in a northwest direction. Glacial striae were not observed but near the site several ridges whose long axis parallel the Trench occur on its floor. Along the Ross River-Watson Lake Road the material exposed in several road cuts into the bases of the ridges consists of dense stony till overlying bedrock. The ice probably originated in Selwyn Mountains but was fed by tributary glaciers flowing from Pelly Mountains. The extensive deposits of sand and gravel which occur on the floor of the Trench and in terraces along its sides were probably formed by water flowing from the melting ice. Silt deposits such as occur along Yukon River valley are uncommon. This material is believed to have been deposited during temporary ponding of the meltwater. A few feet of silt is exposed in cuts along the Ross River-Watson Lake Road near Hoole River. The extent of the deposit is not known.

At Hoole Canyon dam site Pelly River is flowing through a steep-walled canyon situated close to the northeast side of Tintina Trench. The Trench here is about 9 miles wide. Bedrock is exposed almost continuously in the lower half of the walls of the canyon and as islands in the river. The material exposed in the upper parts consists chiefly of coarse-grained, glacio-fluvial gravel which is believed to directly overlie bedrock. Till is not exposed in the site area although deposits of this material may exist in places between the gravel and bedrock.

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[1]Bostock, H.S.: Physiography of the Canadian Cordillera with special reference to the area north of the fifty-fifth parallel; Geol. Surv. Can., Mem. 247, 1948, p. 60.

In the site area the course of Pelly River is U-shaped as the river changes direction several times. The distance across the open side of the 'U' which faces the southwest is about 2,300 feet. In the upstream part of the area the river is flowing in a northwest direction; it swings sharply to the northeast then back to the northwest, to the southeast and finally to its original northwest direction in the downstream part.

The jointing and bedding in the various rock types present have doubtless influenced the direction in which the river flows. In the upstream and downstream parts of the site area it is flowing parallel to the bedding and in the centre part closely follows a prominent joint set in the igneous rocks.

Bedrock at the proposed site consists chiefly of quartzite and limestone intruded by irregular masses of fine- to medium-grained, serpentinized ultrabasic rocks. A small exposure of more recent volcanic rock occurs in the upstream end. The intrusive rocks occur, in general, in the centre of the dam site whereas the sedimentary rocks are exposed in the upstream and downstream sections. The roughest and most dangerous places in the river, from the standpoint of navigation, occur where the contacts between intrusive and sedimentary rocks cross the river. This is especially true in the downstream part of the site where there is a visible drop of about 3 feet in the water when the river passes from intrusive to the softer, less dense, sedimentary rocks.

Unconsolidated Deposits

Three types of unconsolidated deposits were identified at Hoole Canyon dam site. They are as follows:

1. Recent Alluvium: Very little Recent alluvium is exposed at the site. The steep, rock walls of the canyon have confined the river in its channel and thus prevented the formation of flood plain deposits. In the few narrow areas along the edge of the river where alluvium does exist it is usually mixed with

angular fragments of local bedrock and large, rounded boulders which have fallen from the coarse-grained gravels overlying bedrock. The Recent alluvium is coarse-grained material consisting chiefly of rounded to subrounded rock fragments ranging from pebble size to boulders several inches in diameter. About 20 per cent of the material consists of sand. It is not believed there is sufficient Recent alluvium present to warrant consideration as a construction material. The depth of the alluvium underlying the river is not known but it is not believed to be great. Consequently the quantity which will be excavated during construction of the dam will be small.

2. Glacio-fluvial (sand and gravel): This material consists chiefly of coarse-grained, sandy gravel containing numerous rounded to subrounded boulders up to 10 inches in diameter. Most of the boulders are ultrabasic and porous, volcanic rocks similar to bedrock exposed at the dam site or immediately upstream. The percentage of fine material present, i.e. that passing the 200 sieve, is unusually low suggesting the gravel was deposited by relatively fast-flowing water.

The gravel is common throughout the dam site area. It is exposed in considerable thicknesses in the upper parts of both abutments where in places it can be seen to directly overlie bedrock. The upper 24 inches is frequently weathered to a brownish-orange, partially cemented material. In this weathered zone the surfaces of the coarse-grained, ultrabasic rock fragments are soft and easily broken. In places the gravel is overlaid by a thin, irregular 2- to 3-foot thick deposit of fine- to medium-grained sand. Grain-size analyses curves and moisture contents of 3 frozen samples of the sand are included under the heading "Frozen ground".

The permeability of the gravel is probably high. Consequently, as the surface of bedrock exposed in the abutments seldom exceeds 2,600 feet in elevation, considerable gravel will probably have to be removed and replaced with more impervious material before a dam with a crest elevation greater than 2,600 feet can be constructed.

The gravel has been used as base-course material on the Ross River-Watson Lake road with satisfactory results. An attempt was made to obtain suitable surface-course material by screening out the cobbles and boulders greater than 3 inches in diameter. The material obtained was not too satisfactory because of the lack of fine particles, i.e. those passing the 200 sieve. The grain size analyses curves for samples of pit-run gravel (Nos. 5, 11 and 18) and for the sand (Nos. 6 and 7) which are included at the end of this report all indicate the low percentage of fine material present.

3. Talus: Talus is the thin deposit of loose rock fragments lying on the less steep parts of the walls of the canyon. Accumulations of similar material, 15 or more feet in thickness, frequently occur along the toes of the steeper slopes.

Talus is the result of mechanical disintegration of adjacent bedrock. The size and shape of the fragments depends upon the type of source rock. Talus originating in the quartzite consists of small, platy, sharp-edged, angular fragments only a small percentage of which are greater than 6 inches in diameter. Talus from the limestone consists of rectangular blocks ranging from an inch to more than 3 feet in size. The fragments of ultrabasic rocks vary from sand-size particles to boulders several feet in diameter. The highly serpentinized igneous rocks usually yield small, angular fragments. In most instances bedrock breaks along joint, bedding or fault planes. The size and shape of the fragments in the talus is an indication of the manner in which the rock will break when blasted and consequently the rock which will provide the most suitable riprap or rock fill. The limestone and least serpentinized ultrabasic rocks are believed to be the most suitable sources for these construction materials.

Bedrock

General Description

Bedrock exposed at Hoole Canyon dam site consists chiefly of massive, ultrabasic rocks which have intruded thin-bedded, brittle quartzites and buff-weathering, crystalline limestone. The ultrabasic rocks, consisting of peridotite and pyroxenite, are exposed along both sides of the river in the centre part of the dam site area. In places these rocks have been highly serpentinized. Fracture fillings consisting of veins of serpentine and minor quantities of chrysotile asbestos are common. These vary from one-quarter to 4 inches in width and up to 50 feet in length. The bands represent planes of weakness in the rock and result in a decrease in its strength and durability. The rock usually fractures along them leaving a thin film of serpentine on the freshly exposed surfaces. Many of the fragments in the talus derived from ultrabasic rocks are covered in part with a thin coating of soft, greenish, greasy serpentine. The attitudes of these fractures and hence of the bands of serpentine are depicted on the accompanying fracture rosette.

Bedrock in the downstream part of the site consists of thin-bedded quartzite along with massive limestone in beds ranging from 2 to more than 10 feet in thickness. Bedrock in the upstream part consists almost entirely of limestone with only a few narrow beds of quartzite. In this area an 8-foot sill of Tertiary basalt intruding quartzite is exposed on the right side of the river.

The quartzite ranges in colour from white to black. The thickness of the individual beds varies from 1 to 6 inches with most about 2 inches. It is a hard, brittle rock which when cut by a fault shatters into small, angular fragments resulting in a zone of badly shattered rock 4 to 6 feet in width. This is common in the downstream part of the site area where several small faults occur in the quartzite. The rock fragments in these shattered zones are frequently covered with a thin coating of brown, iron-bearing carbonates and oxides probably deposited by groundwater.

The limestone is a fine- to medium-grained, light grey, crystalline rock which weathers to a buff colour. Although the bedding is extremely difficult to identify the thickness of the beds is believed to vary from 2 feet where it is interbedded with quartzite to 10 feet in the more massive exposures. Many of the thinner limestone beds especially those occurring in the downstream part of the site area do not appear on the accompanying geological map.

Bedrock Structures

Jointing is the most common structure in bedrock exposed at the dam site. In the ultrabasic rocks the joint fractures are usually parallel to the bands of serpentine and chrysotile and consequently the attitudes of both were included on the one fracture rosette. The most prominent fractures in the ultrabasic rocks strike between north and north 10 degrees east and, in general, dip steeply to the east. A second set is almost at right angles to the first and dips in a northerly direction. A third set intersects the others at about 45 degrees and dips steeply in both directions. This latter set closely parallels the river during its northwest course through the site area. The spacing of the individual fractures varies from a few inches to several feet.

The attitudes of the bedding in the quartzite and limestone in the downstream part of the site area are fairly regular striking a few degrees south of east and with dips that are close to vertical. Here the bedding intersects the river at about 45 degrees and apparently closely parallels the contact between the sediments and ultrabasic rocks. The area is located on a bend in the river immediately downstream from the contact. The changes in direction of the river here is an example of how lithology and its associated structures can control the course of a stream. At the point where the river crosses the contact from the igneous to the sedimentary rocks it is flowing parallel to a prominent joint set in the igneous and at right angles to the bedding in the sediments. It immediately changes course and is flowing parallel to the bedding not far downstream from the dam site area. The attitudes of the bedding in the upstream part of the site area are more variable. This is probably due to some extent to deformation resulting from intrusion of the igneous rocks. In several places close to the contact with the igneous rocks the beds are contorted and tightly folded. However, in the extreme upstream area the bedding is regular striking in a general northeast direction at right angles to the course of the river.

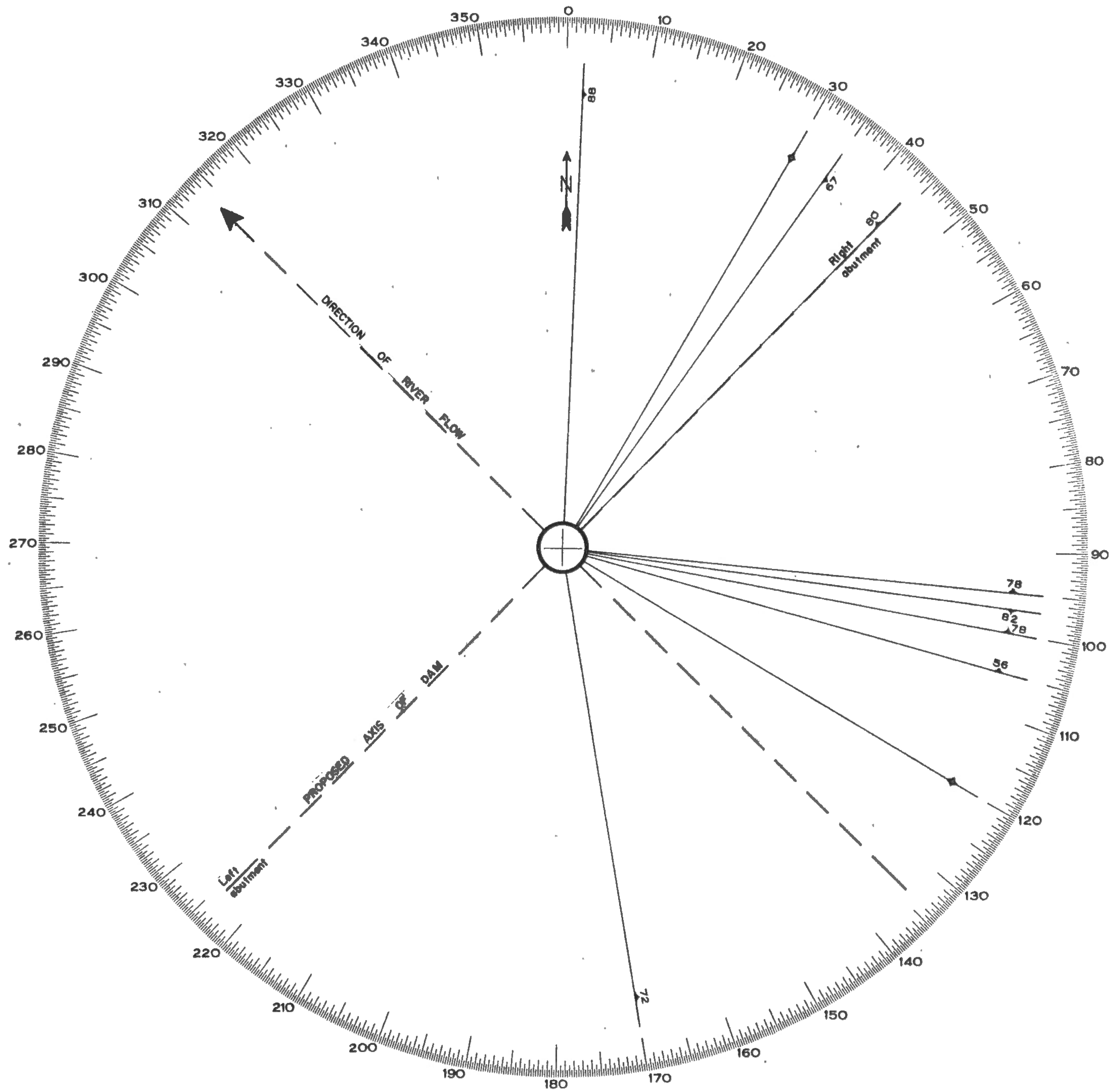
Faulting at the site is confined chiefly to the quartzite in the downstream part. Some are bedding faults, i.e. their strike and dip are parallel to that of the strata but most intersect the bedding at angles up to 30 degrees. The dip is usually close to vertical. One large fault occurs in the right wall of the canyon about 1,200 feet upstream from the lower end of the site. Here a bed of limestone about 12 feet in width has been brought up against quartzite. An irregular deposit of soft, yellow-white powder probably deposited by groundwater occurs along this fault. The significance of this deposit is discussed briefly in the section on groundwater.

The sedimentary rocks exposed in the upstream end of Hoole Canyon consist mainly of thick-bedded limestone. The local folding in the limestone may have resulted from the relief of stresses set up in these rocks prior to or during the intrusion of the ultrabasic rocks whereas the same stresses in the brittle quartzites exposed in the downstream part were relieved by faulting.

Quality of Bedrock

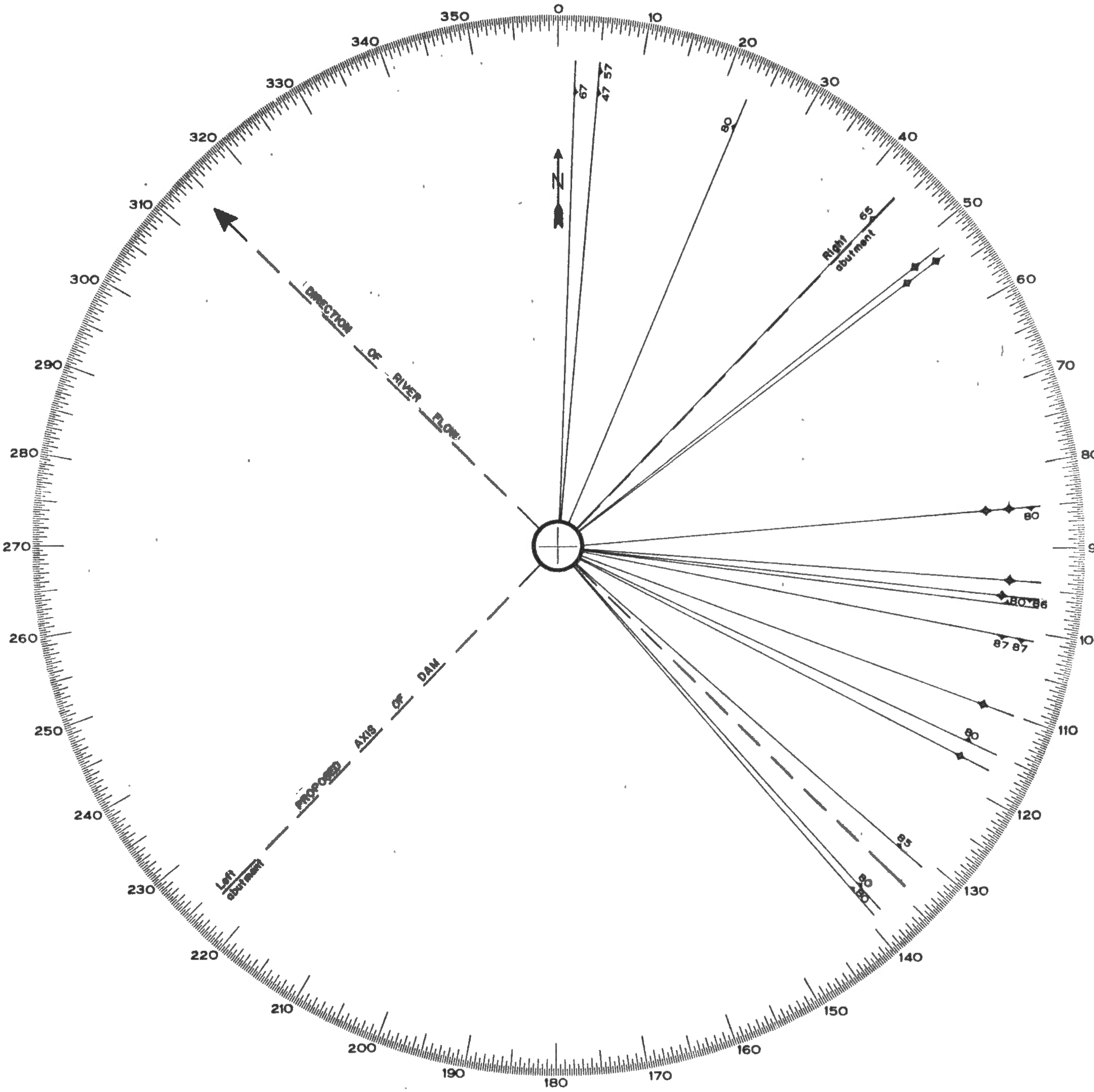
The most competent rock exposed at Hoole Canyon is the thick-bedded limestone that occurs at its upstream end. It is believed this rock would provide suitable foundation and abutment material for the proposed dam. There are few faults present and, although the rock is of the soluble type there are no solution cavities visible in the limestone exposed in the walls of the canyon. The tight folding present does not appear to have lowered the competency of the rock mass.

In this area the limestone is exposed to approximate elevation 2,550 in the canyon walls. Test borings should be put down to determine if bedrock surface



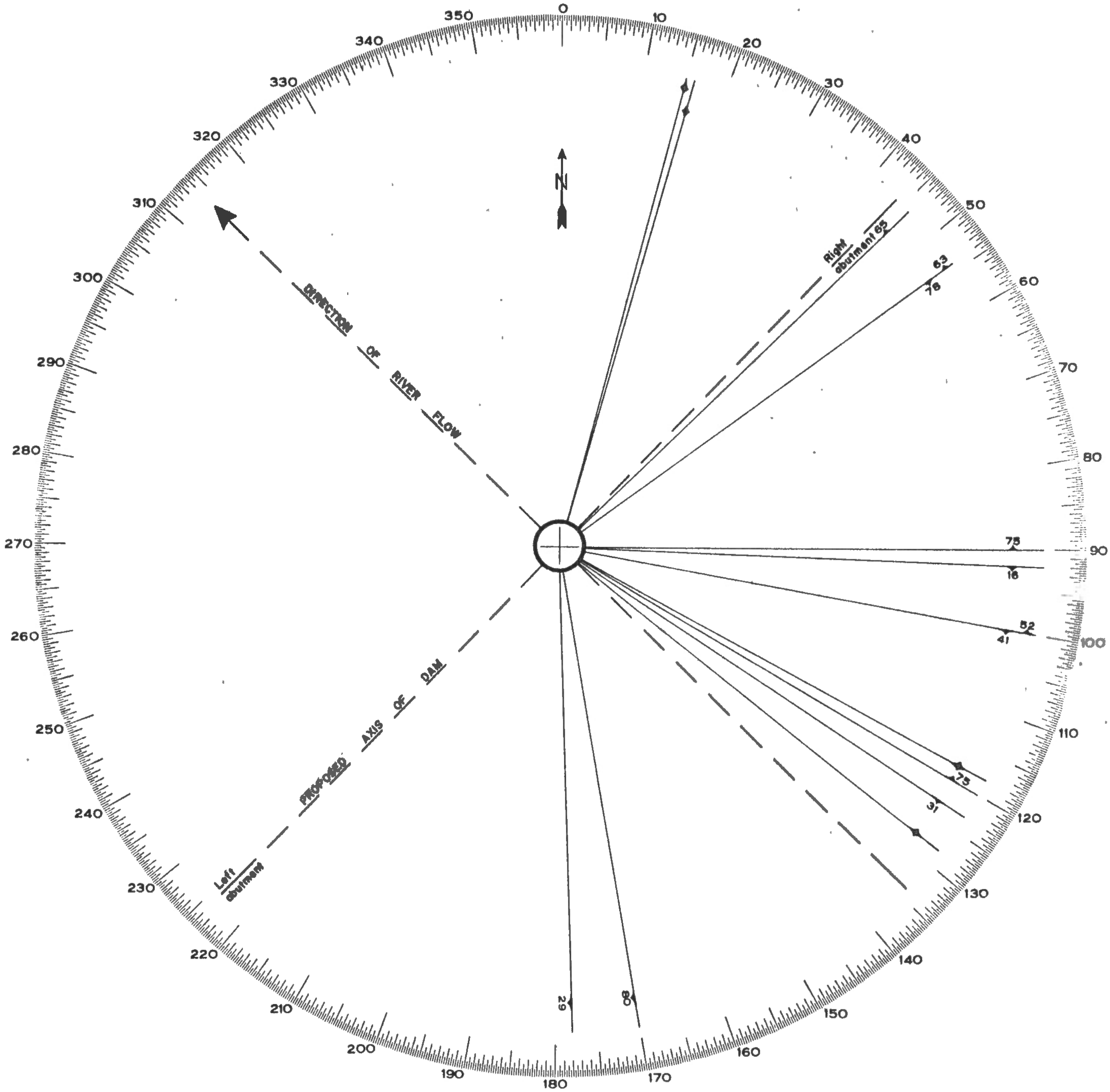
BEDDING ROSETTE

The above illustration presents diagrammatically the direction and dip of bedding in limestone exposed at Hoole Canyon dam site.



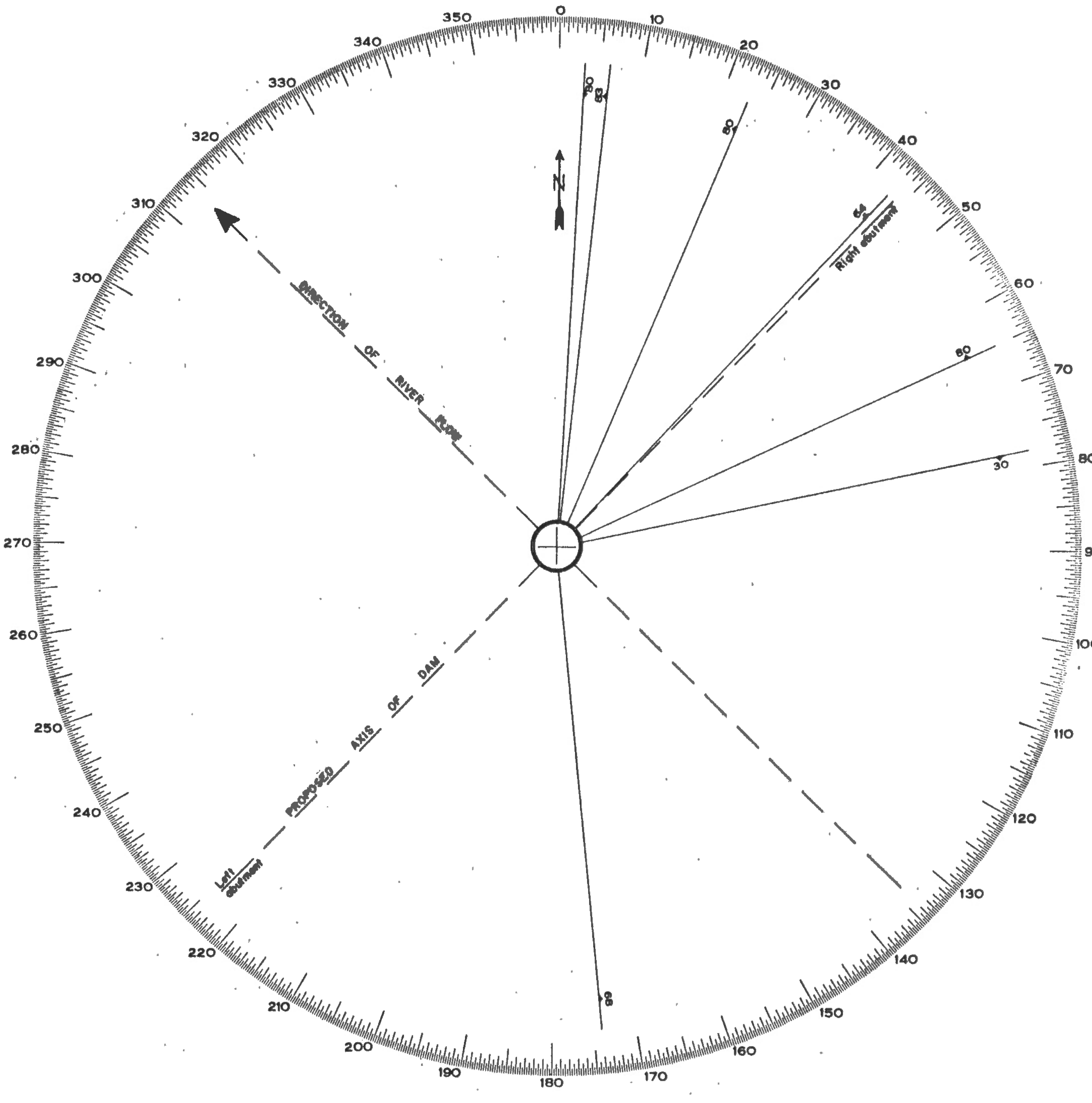
BEDDING ROSETTE

The above illustration presents diagrammatically the direction and dip of bedding in quartzite exposed at Hoole Canyon dam site.



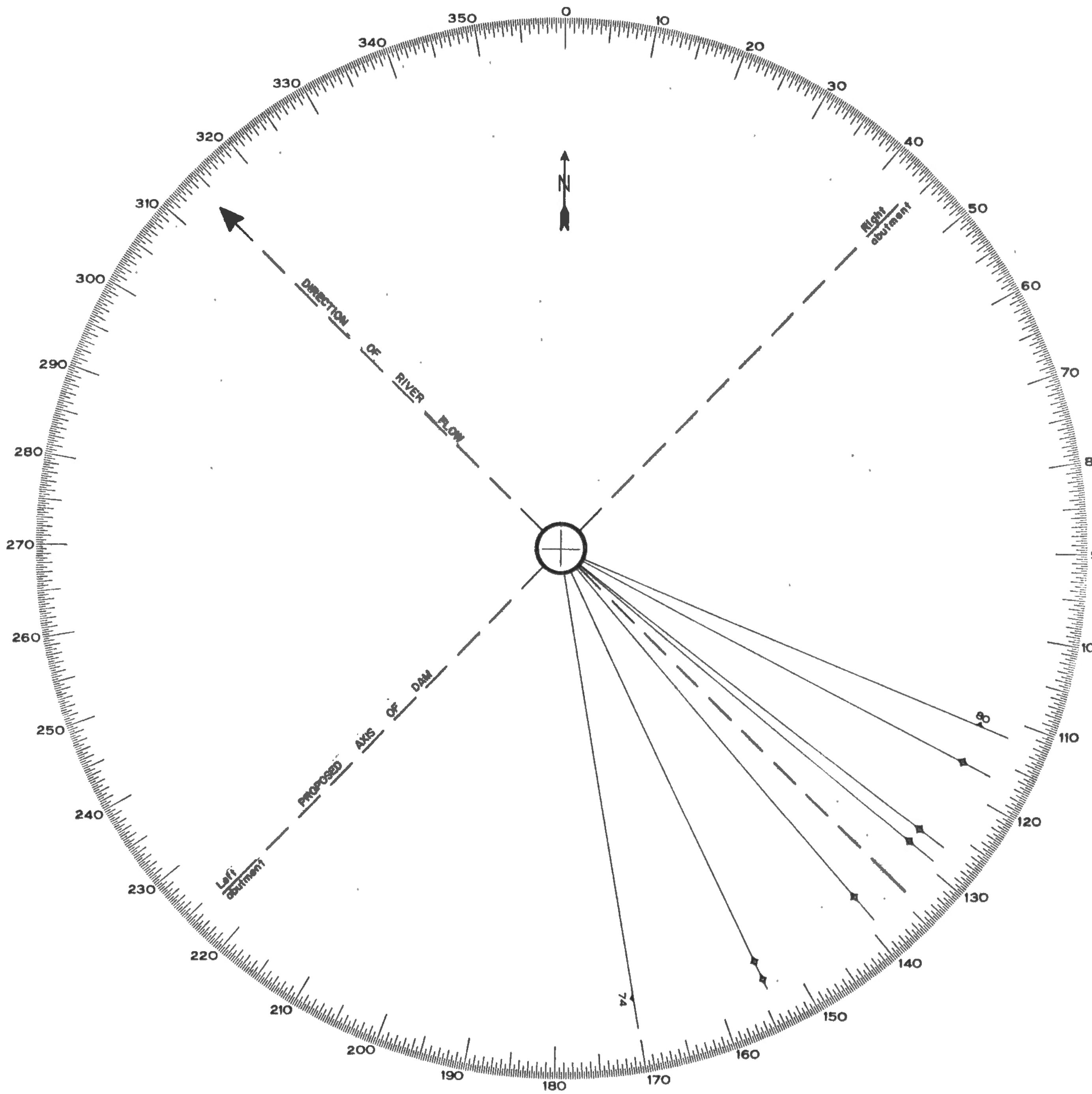
JOINT ROSETTE

The above illustration presents diagrammatically the direction and dip of jointing in limestone exposed at Hoole Canyon dam site



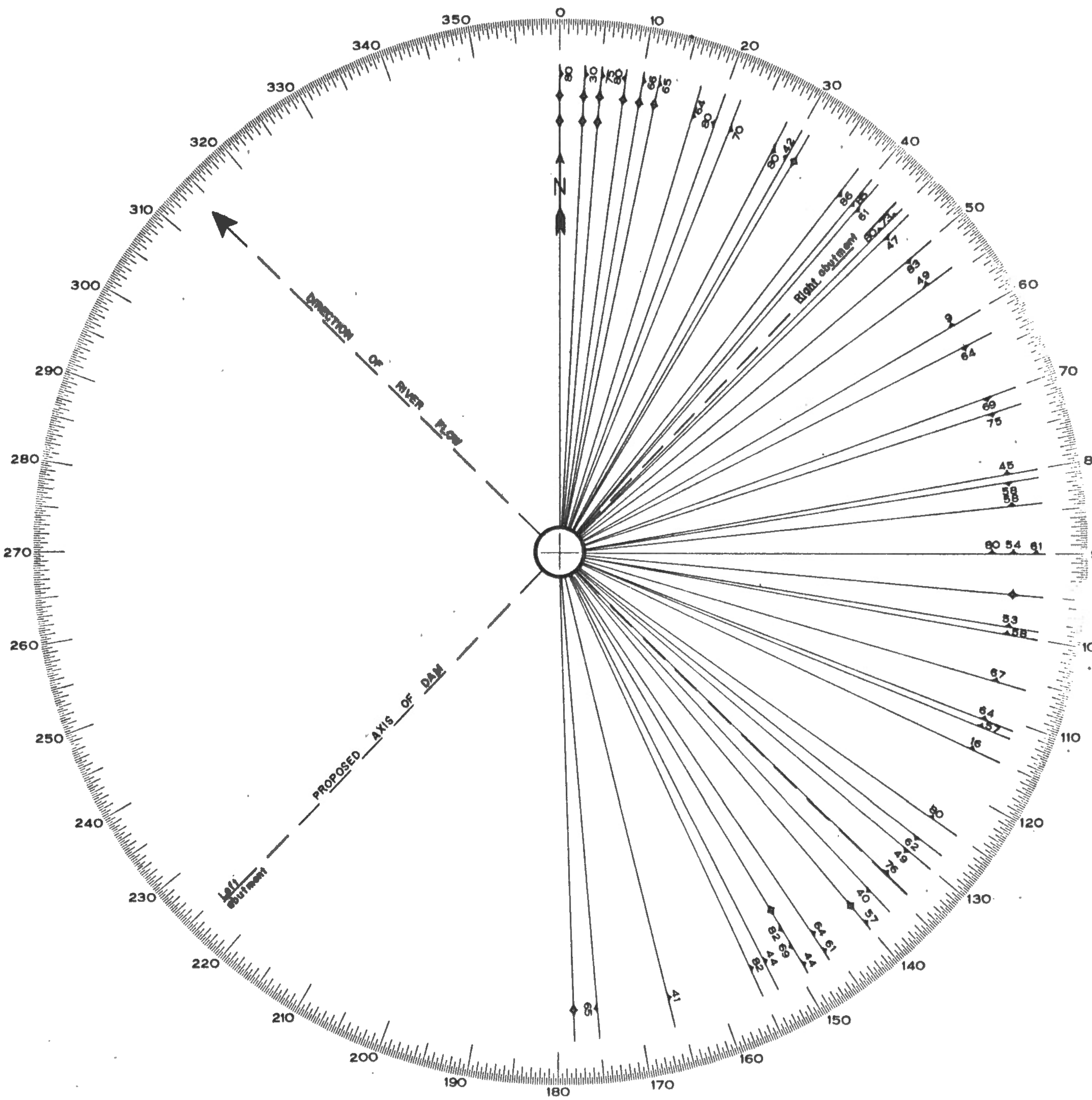
JOINT ROSETTE

The above illustration presents diagrammatically the direction and dip of jointing in quartzite exposed at Hoole Canyon dam site.



FAULT ROSETTE

The above illustration presents diagrammatically the direction and dip of faulting in quartzite exposed at Hoole Canyon dam site.



FRACTURE ROSETTE

The above illustration presents diagrammatically the direction and dip of fracturing in igneous rocks exposed at Hoole Canyon dam site.

levels off above this elevation to form a bedrock terrace or continues upward at a reduced slope beneath the gravel. Vertical borings should also be put down to determine if the limestone continues to depth or is underlain by ultrabasic rocks. The possibility that the porous volcanic rocks which are exposed upstream from the site may extend beneath this area should be investigated.

From the standpoint of topography the most obvious place to locate the dam is in the centre part of the site area where the intrusive ultrabasic rocks are exposed. However, the presence of soft, greasy serpentine which is common in these rocks indicates they may be dangerous to construction. The serpentine occurs throughout the rock mass as pale green crystals probably resulting from the alteration of pyroxene and amphiboles and as fracture fillings which appear as numerous parallel bands extending for many feet throughout the rock. The bands of serpentine are important in considering these rocks as foundation or abutment material as they would appreciably lower the resistance of the rock to sliding. Most of the bands are either parallel to the river or intersect it at about 45 degrees. The dips are variable ranging from 45 degrees in either direction to vertical. In regard to the construction of tunnels in serpentinized rocks Terzaghi[1] has stated that "experience indicates the occurrence of large quantities of serpentine in a rock may be associated with exceptionally heavy pressure on the tunnel support. This association probably results from the fact that the alteration to serpentine involves a volume expansion which creates severe internal stresses in the body of rock subject to alteration".

Similar ultrabasic rocks were encountered in a diamond drill hole located on the left side of Hoole River about 4 miles upstream from its mouth (about 13 miles southeast of the dam site). It was found that several irregular zones of soft, broken rock existed in the ultrabasics from which it was impossible

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[1] Terzaghi, Karl: Rock Tunneling with Stul Supports; Section 1, The Commercial Steel Shearing and Stamping Co., Youngstown, Ohio, 1946.

to obtain core. The material brought up by the drill consisted of a greenish mud containing numerous small, angular fragments of serpentine. The rock was not weathered nor was there any loss of drilling water. The latter is an indication the permeability of the rock mass is low.

As in the case of the limestone further upstream the surface elevation of the ultrabasic rocks where they are exposed in the walls of the canyon seldom exceeds 2,550 feet in elevation.

The bearing capacity of the steeply-dipping quartzite beds in the downstream part of the canyon is doubtless less than if the beds were flat-lying. It is believed, however, these rocks will provide satisfactory foundation and abutment material. In this area the right end of the dam would extend across a narrow, gravel-covered terrace underlaid with quartzite and limestone to a ridge of ultrabasic rocks covered with a thin deposit of gravel. In the left abutment area the quartzite is exposed only to elevation 2,490. The quartzite is tight except along the zones of shattered rocks associated with faulting. Grouting will be necessary to seal these and to consolidate the rock.

Engineering Considerations

Depth of Overburden

Most of the overburden in the dam site area consists of glacio-fluvial sand and gravel. This is part of a large deposit of similar material which extends for many miles beyond the limit of the area included in the accompanying geological map. In the site area the glacio-fluvial material is believed to directly overlie bedrock. Test borings will be required to determine its thickness which will probably vary from a few feet on the ridge which projects against the right side of the river in the downstream part to 80 or more feet as indicated by the results of seismic line No. 1.

The elevation of bedrock surface across the open end of the 'U' formed by Pelly River is probably about 2,530 ± 10 feet. This would include the area in which the two seismic lines are located. In the area immediately downstream from seismic line No. 2 bedrock surface probably continues at much the same elevation for 250 to 300 feet and then slopes downward toward the river where it is exposed at approximate elevation 2,490. Here the maximum thickness of overburden occurs at the top of the bluff and is of the order of 45 feet. Between the river and the upstream end of seismic line No. 1 the depth of overburden varies from about 50 feet at the seismic line to a few feet in the wall of the canyon. The thickness of overburden exposed in the upper part of the canyon walls depends upon the upward slope of bedrock surface away from the bluff. The maximum thickness of overburden within the site area probably seldom exceeds 50 feet. The thickness of the alluvium beneath the river is believed to vary from 15 to 20 feet.

Proposed Location of the Dam

From the viewpoint of topography the best location of the dam would be in the centre of the site area. Here at one point the river is only about 75 feet wide and the walls of the canyon rise steeply to heights of more than 100 feet. The water would be diverted across the open end of the 'U' formed by the river to a power-house situated along the base of the bluff in the downstream part of the site area immediately upstream from the small rocky islands in the river. The power canal would be about 2,000 feet in length and would cross the area where the two seismic lines are located. In this scheme the power-house would be founded on the competent quartzite but the abutments and foundation of the dam would consist of the less satisfactory ultrabasic rocks. It is suggested a better location for the dam would be further upstream in the area where limestone is exposed. The power canal would have to be shifted slightly but the power-house would remain in the same location. The drop in the river between the two sites is about 15 feet. Consequently the height of a dam located at the upstream site could be that much lower and still provide the same pool elevation. As pointed out previously test borings will be required to determine if the upstream site will be satisfactory. The presence of ultrabasic or volcanic rocks underlying or intruding the sediments should be ascertained as well as the upward slope of bedrock surface in the abutments. Other potential sites for the dam would be at the downstream end of the canyon where the quartzites are exposed or upstream from the canyon where volcanic rocks exist. The latter rocks are similar to those at Whitehorse Rapids and Fort Selkirk dam sites. Their porosity is high but the cavities are not interconnected and consequently do not increase the permeability of the rock. The possibility the volcanic rocks may overlie permeable, unconsolidated sand and gravel should not be overlooked.

Construction Materials

Aggregate

Suitable aggregate for the concrete parts of the dam structures can probably be obtained from the extensive deposits of glacio-fluvial sand and gravel which occur at and near the site area. Some of the glacio-fluvial material exposed along the Ross River-Watson Lake road was found by the Department of Public Works to be too coarse-grained and dirty for direct use in concrete bridge abutments. It was necessary to wash, screen and reblend the gravel before a satisfactory quality was obtained. Samples (Nos. 5, 11 and 18) from which the grain size analyses curves included at the end of this report were prepared were taken from deposits which appeared from field examination to be potential sources of suitable aggregate. They represent material in specific localities only and are not indicative of the great mass of glacio-fluvial material present. Most of the cobbles and boulders over 3 inches in diameter in the gravel consist of serpentinized ultrabasics or quartzite. The former would be deleterious in aggregate but would be screened out during processing. There is very little chert or shale in the gravel. Suitable aggregate could probably also be obtained by crushing the limestone exposed at the site.

Impervious Material

There is no shortage of material suitable for the impervious core of an earth- or rock-fill dam in the area about the site. Laboratory investigations of two representative samples of till (Nos. 3 and 4) taken from cuts along the Ross River-Watson Lake road indicate this material would be suitable. The samples were taken at points where the road has intersected one of the many elongated ridges which trend parallel to the ice movement in Pelly River valley. The quantity of till available is unlimited. Grain size analyses curves as well as some of the index properties of the till are included at the end of this report.

Pervious Material

Pervious materials required for construction of an earth dam could be obtained by processing the gravel described in the section on aggregate. There are unlimited quantities available within a few miles of the site.

Riprap and Rock Fill

The ultrabasic rocks in which little or no serpentine is present should provide excellent riprap or rock fill. In the few places in the site area where there are only minor quantities of serpentine present in these rocks the talus fragments are very large ranging up to several feet in diameter. Tests should be made on the highly serpentinized rock to determine the effect of the serpentine on its soundness. In places the highly altered rocks are soft and weathered and have no use as a construction material. To obtain satisfactory riprap or rock fill from the ultrabasic rocks a considerable amount of sorting will have to be done.

The limestone has a lower specific gravity than the igneous rocks but should provide satisfactory rock fill. The fragments of limestone obtained by quarrying will not be as large as those from the ultrabasics especially from localities where the limestone is thin-bedded.

It is doubtful if suitable material could be obtained from the quartzite. The undesirable shapes of the fragments in the talus derived from these thin-bedded rocks is an indication of the manner they will break when quarried.

Groundwater

Two springs about 500 feet apart occur on the right wall of the canyon near the centre of the site area. The water is flowing from coarse-grained gravel exposed in the bluff about 40 feet above bedrock surface (85 feet above the river). An analysis of the dissolved mineral content in the water from one spring is included at the end of this report. The combined flow of the springs including that from several small seepages in the same area was estimated to be about 500 imperial gallons an hour. The low temperature of the water (34° F) along with the total dissolved mineral content (283 ppm.) suggest it is a mixture of water resulting from the thawing of local frozen ground and subpermafrost water which is often highly mineralized.

The rock fragments in the shattered zones associated with faulting are covered with a thin, brown coating of iron-bearing carbonates which was probably deposited by groundwater circulating through the rock. At the time of the investigation all these structures were dry. A soft, yellowish, acid-tasting powder containing considerable iron sulphate occurs along a fault about 1,200 feet downstream from the springs. The following is a partial chemical analysis of this material:

Sample No.	1	2
CaO	0.33%	0.31%
MgO	Trace	Trace
Na_2O	0.06%	0.06%
K_2O	0.20%	0.20%
Fe_2O_3	25.50%	21.00%
SiO_2	5.35%	18.50%
SO_3	38.0 %	31.3 %
Cl	Trace	Trace

Although there is no evidence of groundwater occurring along the fault at the present time it is possible the powder was deposited by a former hot spring. The occurrence of sulphate-bearing water in these rocks is important because of the effect the dissolved minerals may have upon the concrete structures. The following table[1] describes the relative degree of attack on concrete by soils and waters containing various sulphate concentrations:

Relative degree of sulphate attack	Per cent water-soluble sulphate (as SO_4) in soil samples	P.p.m. sulphate (as SO_4) in water samples
Negligible	0.00 to 0.10	0 to 150
Positive[2]	0.10 to 0.20	150 to 1,000
Considerable[3]	0.20 to 0.50	1,000 to 2,000
Severe	over 0.50	over 2,000

[2] Use type II cement. [3] Use type V cement.

[1] Concrete Manual: Bureau of Reclamation; United States Bureau of Reclamation; 1956, p. 12.

Frozen Ground

Frozen ground was observed in test pits put down to depths of 4 feet in the left abutment area and also by digging in the bottom of the shot holes along the upstream end of seismic line No. 1 (August 22, 1964). These have been indicated on the accompanying geological map. The low temperature (34° F) of groundwater in springs in the right wall of the canyon indicates frozen ground probably occurs here as well.

Drive samples of some of the frozen material were taken using BX casing and a 10-pound sledge hammer for a determination of its moisture content. The results along with those for other samples taken in the area near the site are included on the following pages under the heading "Description of frozen material". The type of equipment used limited the sampling to fine-grained materials. It was not possible to obtain samples of materials containing pebbles or larger rock fragments.

Frozen material around the margin of the reservoir would be thawed by the adjacent, imponded water. Consequently sliding might occur if the water content in the thawed material exceeded the liquid limit. Unfortunately the liquid limits of the soils were not available at the time this report was written and hence no conclusions could be made. There was not sufficient material obtained in samples Nos. 9, 10, 12, 17 and 18 to determine their water content or produce a grain size analysis curve.

Description of Frozen Material

Pit No.	Location	Sample No.	Depth in inches	Description	Group Symbol*	Moisture Content	Visible Ice	Log of test pit in inches
1	Hoole Canyon dam site; 100 feet south of upstream end of seismic line No. 1.	1	18-21	Silt; non-plastic.	ML	22%	Ice lenses to $\frac{1}{4}$ inch.	0-7 = Organic material. 7-10 = Volcanic ash. 10-13 = Organic material. 13-17 = Sand: fine-grained, silty, grey to brown. 17 = Frost line.
1	" "	2	22-25	" "	"	24.0%	" "	18-28 = Silt.
1	" "	3	25-28	" "	"	66.6%	" "	
2	Hoole Canyon dam site; up-stream end of seismic line No. 1.	4	40-42	Sand; fine-grained, minor silt, non-plastic.	SP-SM	28.5%	No visible ice.	0-12 = Organic material. 12-15 = Volcanic ash. 15-44 = Sand: fine-grained, brown, slight weathering in upper 3 inches.
2	" "	5	42-44.5	" "	" "	30.8%	" "	44 = Frost line.
3	50 feet north of test pit No. 1.	6	23-25	Silt; non-plastic	ML	24.6%	Ice lenses to $\frac{1}{4}$ inch.	0-10 = Organic material. 10-13 = Volcanic ash. 13-17 = Organic material. 17-23 = Sand: silty; grey to light brown. 23 = Frost line. 23-28 = Silt.
3	" "	7	25-27	" "	ML	25.1%	" "	
3	" "	8	27-28	" "	ML	25.6%	" "	

* Unified Soil Classification System.

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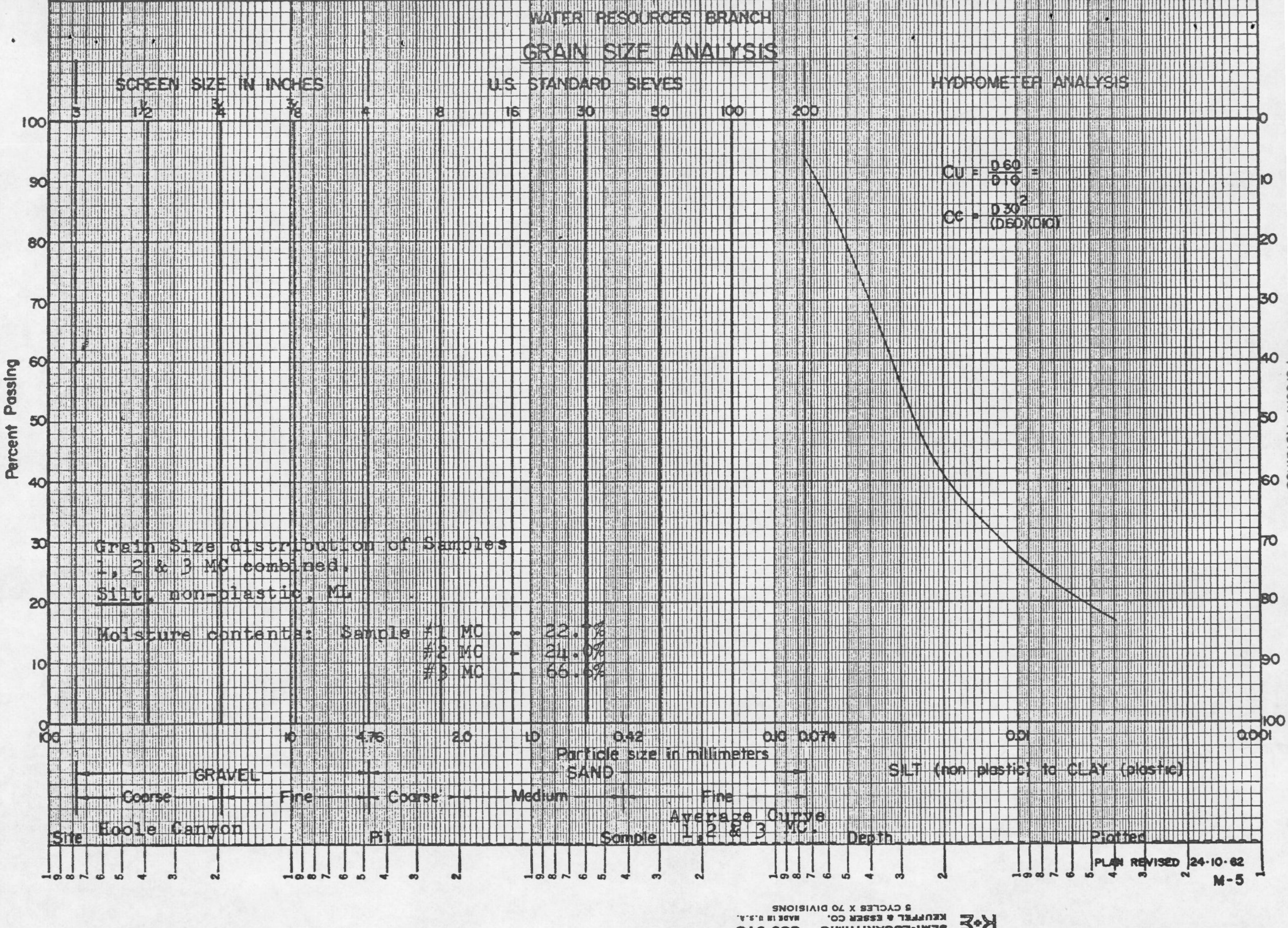

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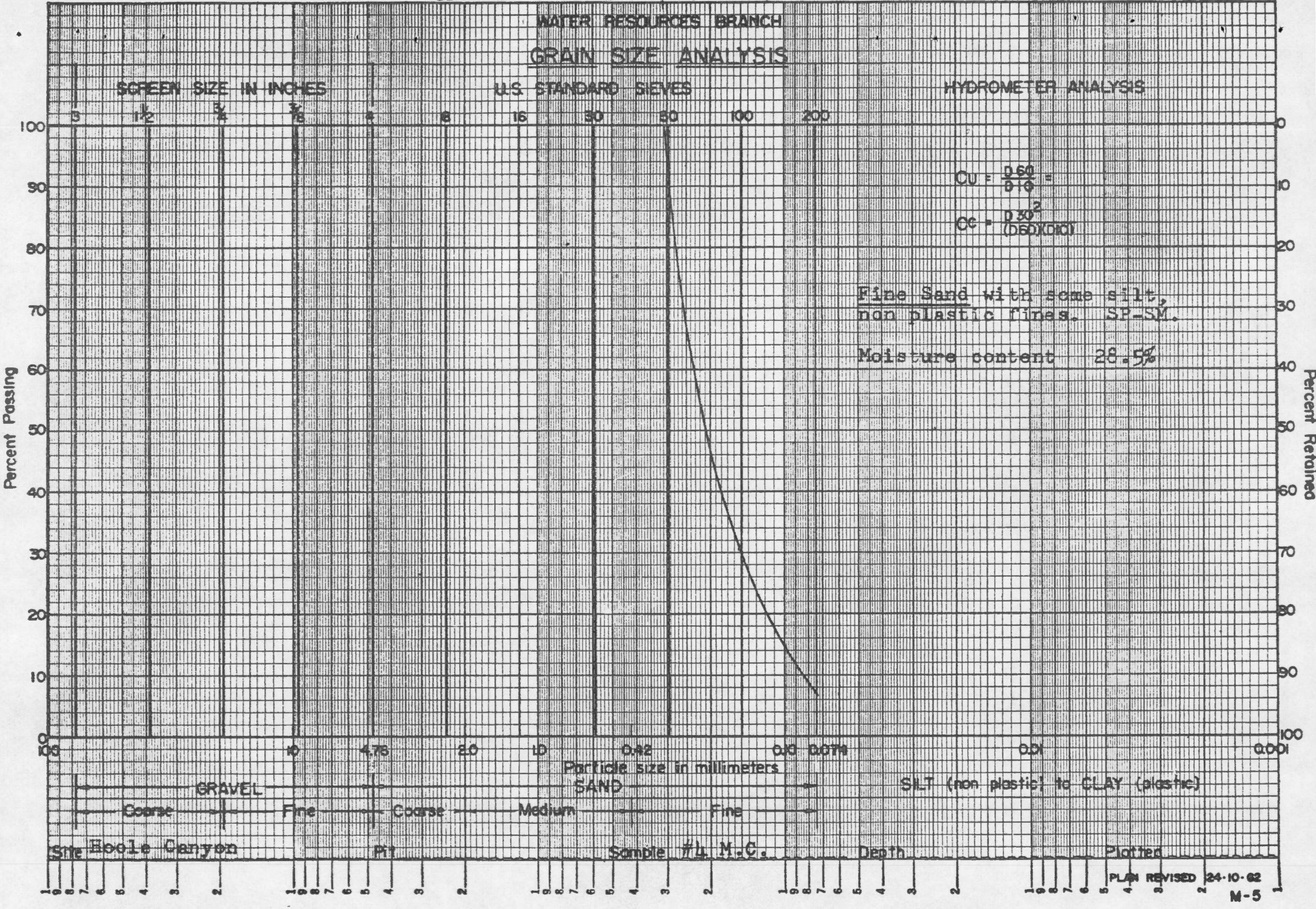

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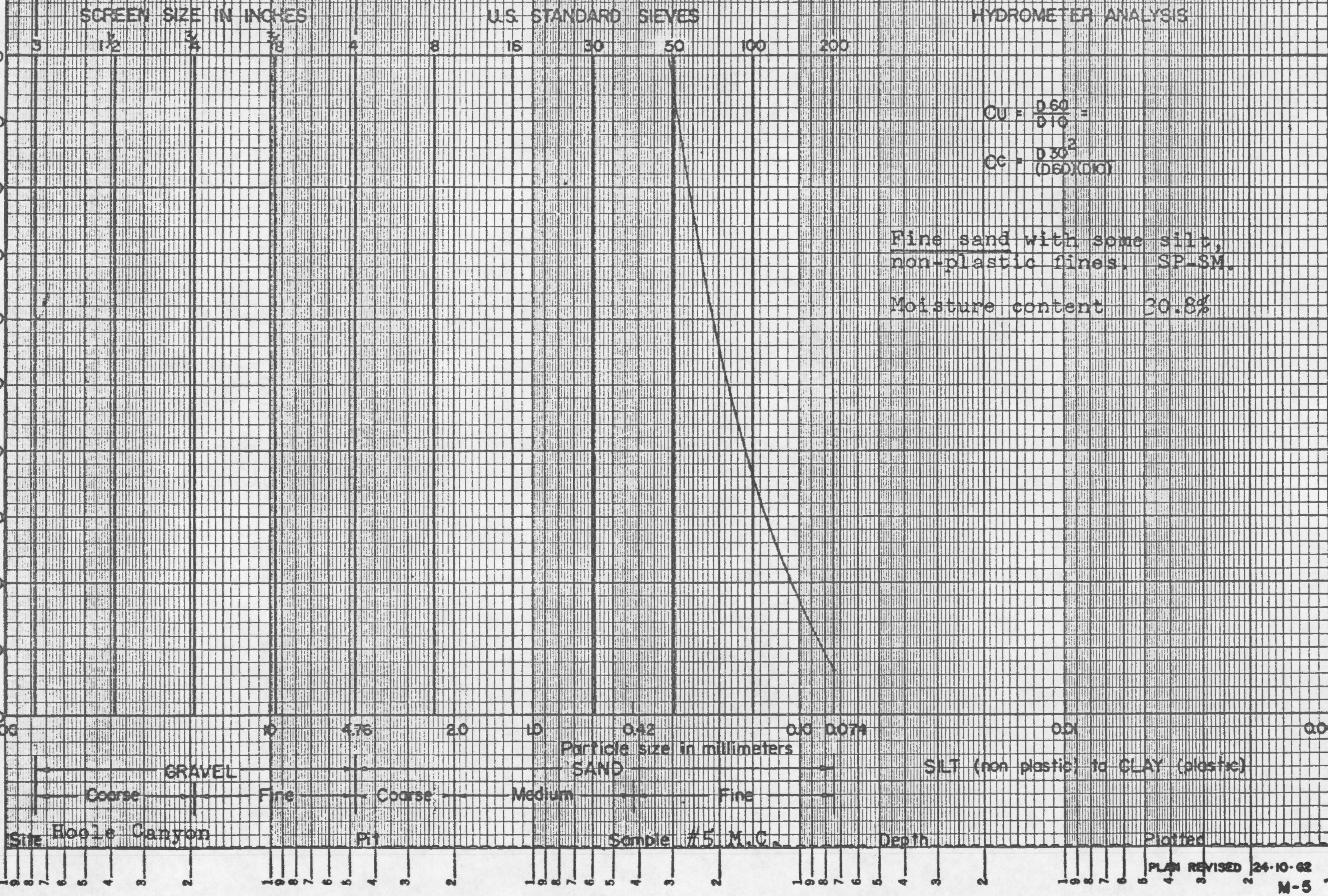
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS



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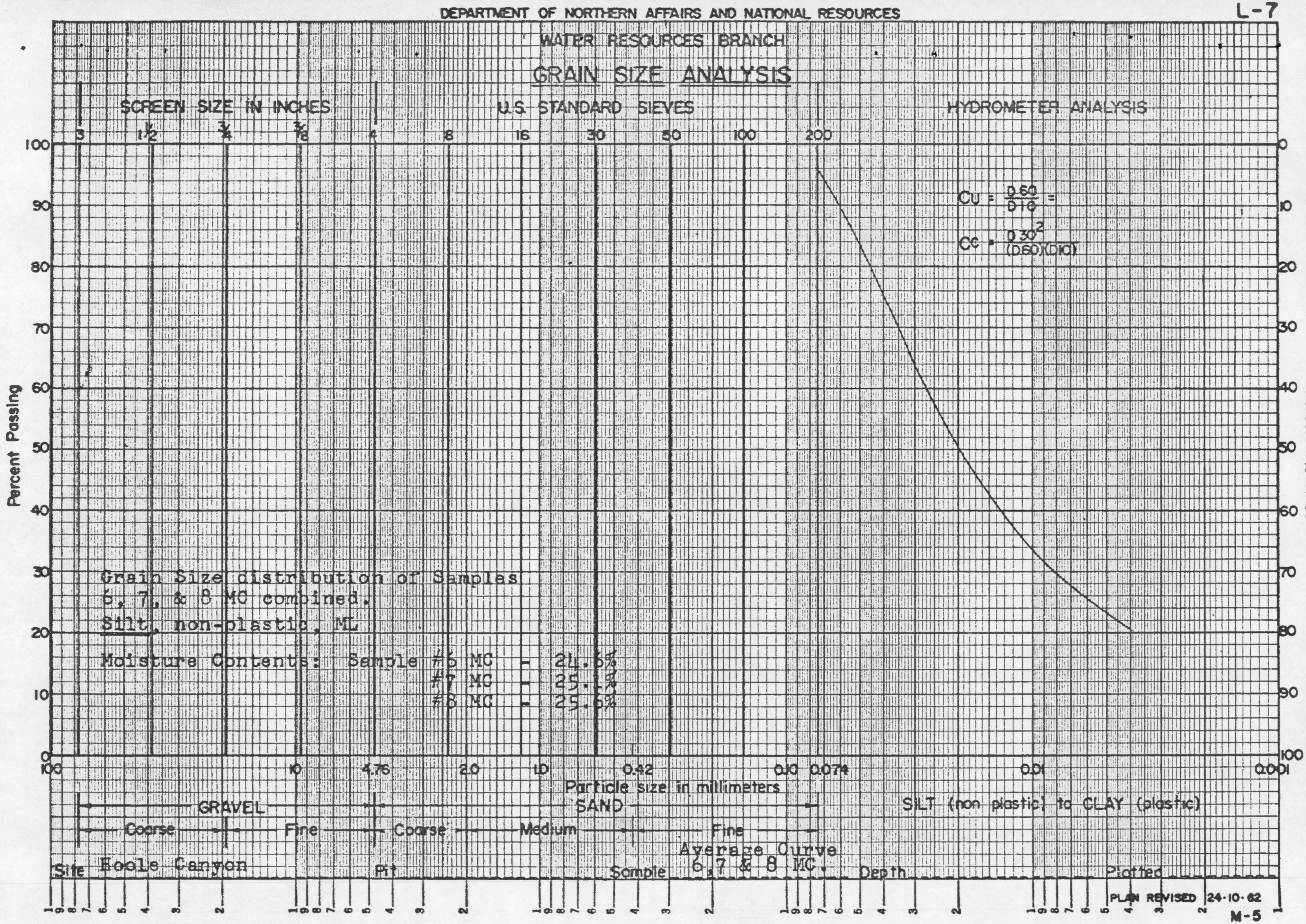
KEUFFEL & ESSER CO. MADE IN U.S.A.
5 CYCLES X 70 DIVISIONS


DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES
WATER RESOURCES BRANCH
GRAIN SIZE ANALYSIS
SCREEN SIZE IN INCHES
U.S. STANDARD SIEVES
HYDROMETER ANALYSIS
3
1½
¾
⅜
4
8
16
30
50
100
200
Cu = D60 / D10 =
Cc = D30² / (D60)(D10)
Percent Passing
Percent Retained
Grain Size distribution of Samples
6, 7, & 8 MC combined.
Silt, non-plastic, ML
Moisture Contents: Sample #6 MC - 24.6%
#7 MC - 25.1%
#8 MC - 25.6%
100
10
4.76
2.0
1.0
0.42
0.10
0.074
0.01
0.001
Particle size in millimeters
GRAVEL
SAND
SILT (non plastic) to CLAY (plastic)
Coarse
Fine
Coarse
Medium
Fine
Average Curve
Site Hoole Canyon
Pit
Sample 6, 7 & 8 MC.
Depth
Plotted
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M-5
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Description of Frozen Material

Pit No.	Location	Sample No.	Depth in inches	Description	Group Symbol*	Moisture Content	Visible Ice	Log of test pit in inches
4	250 feet east of Horton Creek; 600 feet south of Watson Lake-Ross River road.	9	30-36	Clayey silt, minor sand.	ML		About 20% by volume.	0-9 = Organic material. 9-12 = Volcanic ash. 12-22 = Organic material. 22 = Frost line. 22-27 = Organic material. 27-51 = Silt: clayey, minor sand, grey.
4	" "	10	47-51	" "	ML		" "	
5	5.1 miles west of Horton Creek;300 feet south of Watson Lake-Ross River road.	11	26-33	Sand; silty, minor gravel, till-like material.	SM	69.6%	Much white, snowy ice.	0-10 = Organic material 10-13 = Volcanic ash. 12 = Frost line. 13-33 = Till-like material, grey, pebbles to 2 inches. Temperature at 24 inches = 32°F.
6	4 miles west of Horton Creek; 100 feet south of Watson Lake-Ross River road.	12	57-61	Till-like material as in sample No. 11.	SM(?)	53.5%	About 25% by volume; ice is white and snowy.	0-12 = Organic material. 12-15 = Volcanic ash. 13 = Frost line. 15-36 = Organic material. 36-61 = Till-like material, many small pebbles. Temperature at 25 inches = 32°F.

*Unified Soil Classification System.

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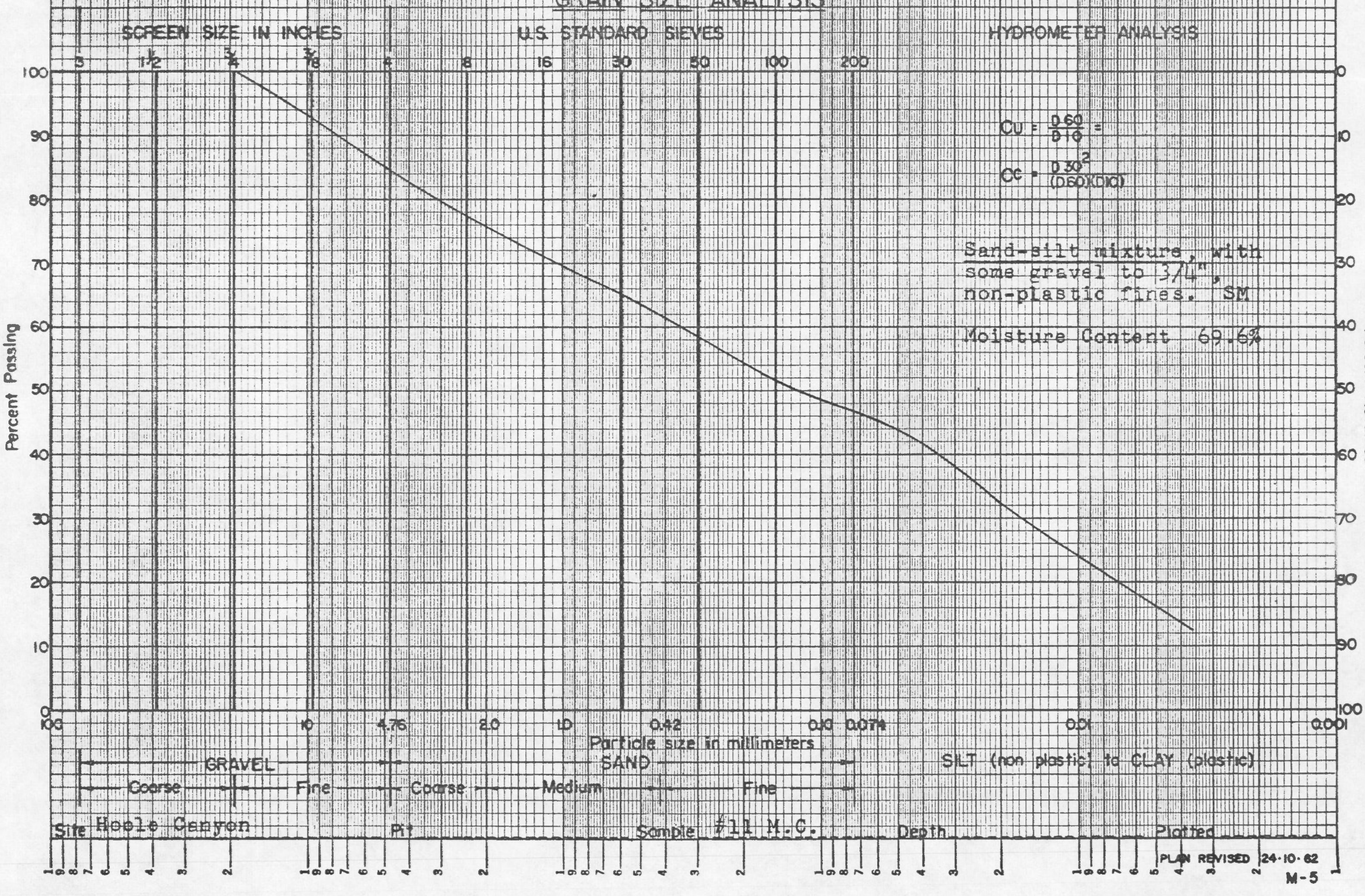
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS



Site Hoole Canyon   Pit   Sample #11 M.C.   Depth   Plotted

PLAN REVISED 24·10·62

M-5

Description of Frozen Material

Pit No.	Location	Sample No.	Depth in inches	Description	Group Symbol*	Moisture Content	Visible Ice	Log of test pit in inches
7	2.4 miles east of Horton Creek; 100 feet south of Watson Lake-Ross River road.	17	32-35	Till-like material; many small pebbles; a few large boulders.		18.1%	Very little	0-11 = Moss. 11 = Frost line. 11-24 = Organic material. 24-28 = Volcanic ash. 28-32 = Organic material. 32-35 = Till-like material; many small pebbles, a few large boulders.
8	27.9 miles east of Horton Creek; 100 feet south of Watson Lake-Ross River road.	18	34-40	Silt; sandy, non-plastic.	ML	133.0% (organic)	Very little	0-6 = Moss. 6-18 = Silt; sandy. 18 = Frost line. 18-47 = Silt; sandy
8	" "	19	40-47	" "	ML(?)	73.8%	" "	" " "

*Unified Soil Classification System.

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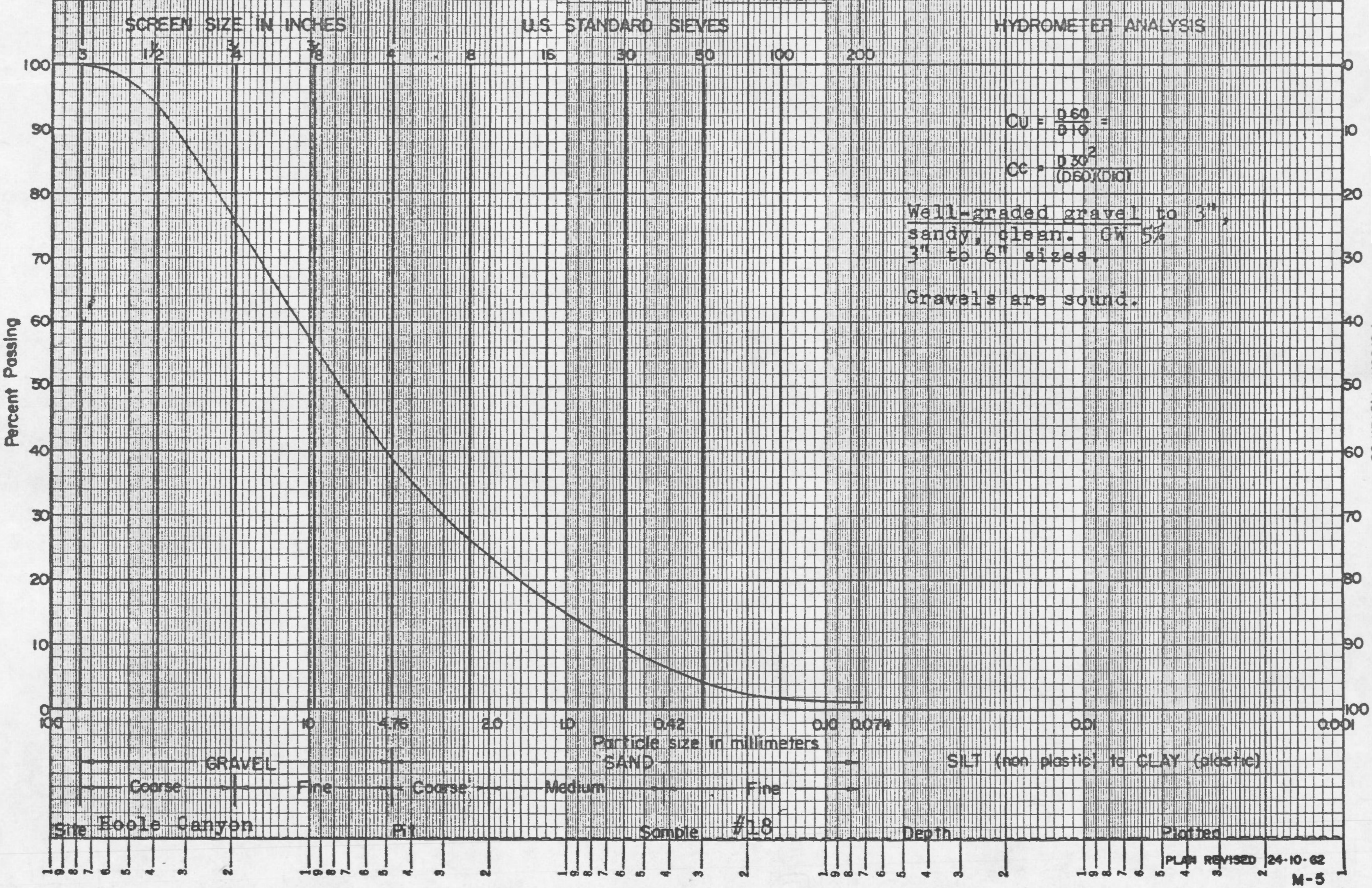
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS



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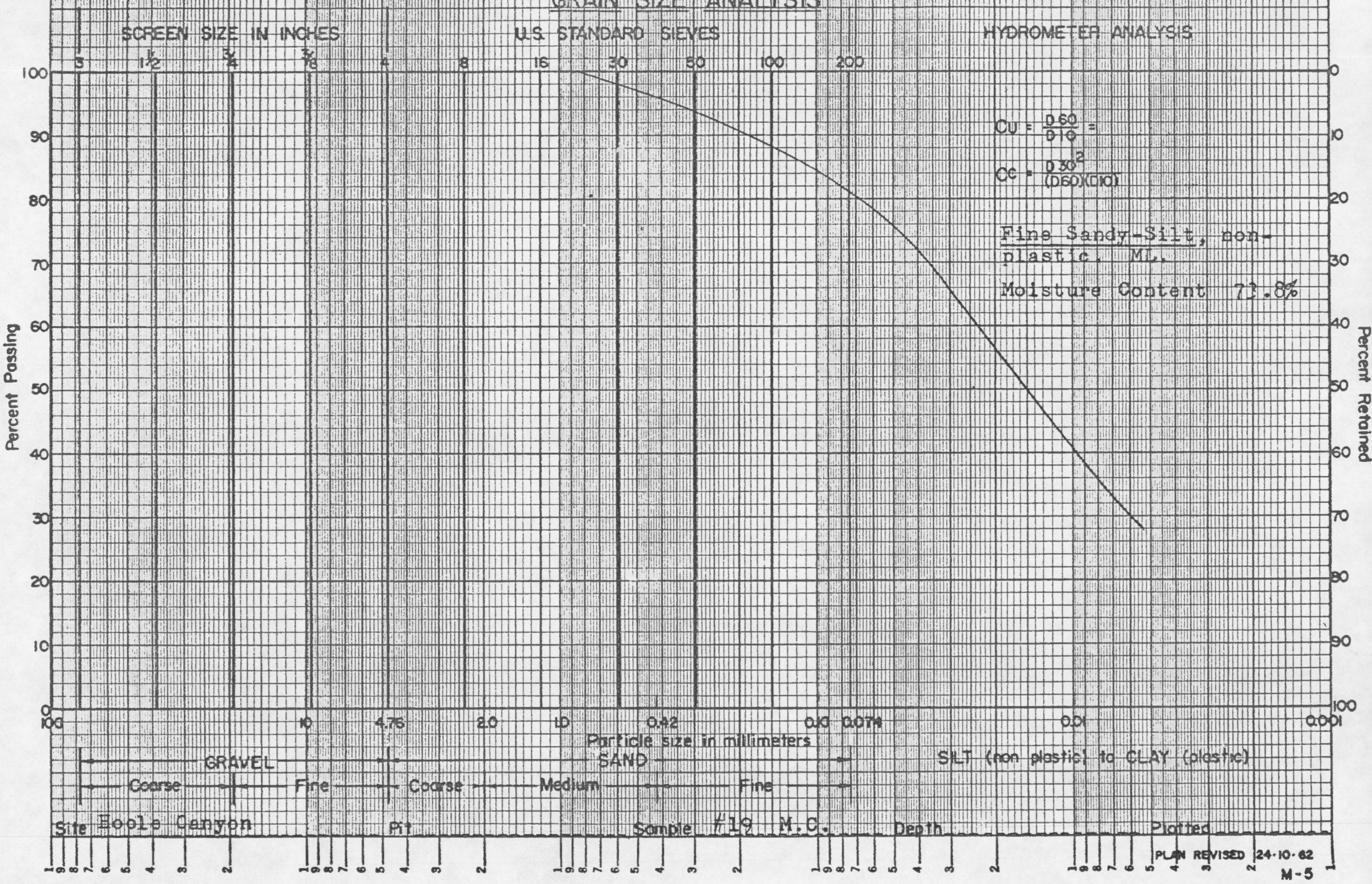
GRAIN SIZE ANALYSIS



Chemical Analyses of Surface and Groundwaters

During 1964 and 1965 several samples of Pelly River water were taken at various locations along the river downstream from the dam site. At the same time the water in five tributary streams which enter the left side of Pelly River upstream from the site were sampled. These streams all have their source in Pelly Mountains and flow in a general northerly direction across Tintina Trench to the River. The water from three springs were also sampled. Two of these occur along the Ross River-Watson Lake road and the other in the right wall of Hoole Canyon. Chemical analyses of the samples were made by the Industrial Waters Section, Mines Branch, Department of Mines and Technical Surveys, Ottawa. The results are included in this report.

During the sampling period there was little change in the mineral content of Pelly River water which corresponds closely to that in streams tributary to the Pelly. Bicarbonate salts of calcium and magnesium constitute the chief mineralization of these waters. There are no salts present in sufficient quantity to be harmful to the concrete or other parts of the dam structures which would be exposed to the water. The reported value of the turbidity should be considered only as indicative. Flash floods may cause a rapid increase in the sediment land. A proper sediment study, therefore, requires regular sampling, often in the case of flash flooding at hourly intervals.

The mineral content of the water from the spring in the right abutment area of the dam site is chiefly calcium bicarbonate. The water is flowing from coarse-grained gravel of glacio-fluvial origin at a point about 40 feet above bedrock surface. There is a considerable difference in the mineral content of the water from the two springs sampled along the Ross River-Watson Lake Road. The chief mineralization of one water is calcium bicarbonate while the other contains a relatively large proportion of calcium sulphate. The reason for this variation in mineral content is unknown. The topography of the two springs is similar. Both are situated on the south-facing slope of an elongated gravel ridge which trends westward along the floor of Tintina Trench. The temperature of the water from all three springs is cold, varying from 34 to 37 degrees fahrenheit.

Chemical Analyses of Surface and Groundwater in the Vicinity of Hoole Canyon Dam Site
(parts per million)

Location	Date	River Discharge	pH	SiO_2	Ca	Mg	Na	K	Fe	CO_3	HCO_3	SO_4	Cl	F	NO_3	Turbidity	Hardness as $CaCO_3$
Pelly River at downstream end of dam site.	July 1, 1964	High Temp. 42°F	7.5	5.1	26.8	7.6	1.0	0.5	1.65	0	87.8	23.7	1.8	0	0	6	48.3
"	Aug. 15, 1964	Low Temp. 51°F	7.6	5.9	33	10.1	1.2	0.6	4.2	0	111	32	0.2	0.19	0.3	0.8	124
"	June 22, 1965	Med. Temp. 47.5°F	7.8	5.2	29.5	8.6	1.3	0.6	0.52	0	101	27.3	0.2	0.14	0	11	109
Pelly River $\frac{1}{4}$ mile upstream from Ross River.	Aug. 15, 1964	Low Temp. 52°F	8.1	5.7	36	11.5	1.2	0.5	0.49	0	120	38	0.3	0.16	0.1	4	138
"	June 22, 1965	Med. Temp. 48°F	7.9	5.2	31.2	9.7	1.3	0.6	0.51	0	109	30.5	0.5	0.15	0	7.0	118
Pelly River $1\frac{1}{2}$ miles downstream from Ross River.	Aug. 15, 1964	Low Temp. 52°F	7.9	6.2	29.1	9.5	1.2	0.5	0.52	0	96.1	32	0.2	0.17	0	5	112
"	June 22, 1965	Med. Temp. 50°F	7.9	5.1	27.5	8.8	1.3	0.6	0.67	0	92.6	30.1	0.5	0.14	0	13.5	105

Chemical Analyses of Surface and Groundwater in the Vicinity of Hoole Canyon Dam Site
(parts per million)

Location	Date	River Dis-charge	pH	SiO_2	Ca	Mg	Na	K	Fe	CO_3	HCO_3	SO_4	Cl	F	NO_3	Turbi-dity	Hardness as $CaCO_3$
Horton Creek at bridge on Ross River-Watson Lake Road.	June 21, 1965	Med. / Temp. 46°F	8.1	7.4	57.4	24.7	3.1	0.9	4.0	0	249	43.8	0.1	0.22	0.1	27	245
Hoole River at bridge on Ross River-Watson Lake Road.	June 21, 1965	Med. / Temp. 46°F	8.1	4.4	38.0	12.2	2.1	0.4	0.18	0	145	27.7	0.5	0.2	0.1	3.3	145
Mink Creek at bridge on Ross River-Watson Lake Road.	June 21, 1965	Med. / Temp. 41°F	8.2	7.3	47.7	11.4	2.1	1.0	0.36	0	184	19.9	0.6	0.22	0.2	4.0	166
Big Campbell River at bridge on Ross River-Watson Lake Road.	June 21, 1965	Med. / Temp. 44°F	7.8	4.7	22	3.8	1.0	1.4	0.02	0	75.6	13.0	0.3	0.15	0	1.2	70.7
Little Campbell River at bridge on Ross River-Watson Lake Road.	June 21, 1965	Med. / Temp. 49.5°F	8.0	6.5	44.0	13.4	2.1	1.4	0.08	0	166	30.8	0.7	0.19	0	0.5	165
Creek crossing Ross River-Watson Lake Road, at mile post 160 from Watson Lake.	Aug. 17, 1964	Low / Temp. 43°F	8.0	8.1	60.5	20.1	2.2	1.0	0.07	0	206	62	0.3	0.21	0.5	0.5	234

Chemical Analyses of Surface and Groundwater in the Vicinity of Hoole Canyon Dam Site
(parts per million)

Location	Date	River Discharge	pH	SiO_2	Ca	Mg	Na	K	Fe	CO_3	HCO_3	SO_4	Cl	F	NO_3	Turbidity	Hardness as $CaCO_3$
300 feet north of Ross River-Watson Lake Road, at mile post 159 from Watson Lake.	Aug. 17, 1964	Spring Temp. 34°F	7.8	9.1	116	45.3	2.6	1.8	0	0	4.7	135	0.1	0.49	0.1	0.3	476
400 feet north of Ross River-Watson Lake Road at mile post 158 from Watson Lake.	Aug. 17, 1964	Spring Temp. 37°F	8.0	11	83.2	31.9	2.4	1.4	Tr.	0	368	38	0	0.21	0.2	0.5	339
South side of Finlayson Lake 1,000 feet north of Ross River-Watson Lake Road and 47.3 miles east of Horton Creek.	June 21, 1965	Lake Temp. 42°F	8.0	7.5	40.2	15.0	2.0	1.1	0.01	0	146	42.9	0.3	0.15	0.3	15	162
Right side of Pelly River in centre of dam site area; 85 feet above river and 250 feet east of station A-5; aquifer is gravel.	Aug. 12, 1964	Spring Temp. 34°F	7.7	9.8	64.8	27.0	3.3	1.9	2.8	0	296	28	0.4	0.15	1.8	0.3	273

Grain Size Analyses Curves

Seven soil samples, each weighing about 35 pounds, of potential construction materials were taken at several different localities near the site and sent to the Soils Laboratory of the Water Resources Branch in Vancouver for testing. The grain size analyses curves included in this report were prepared in Vancouver. Only one sample was taken in the dam site area the others are from exposures along the Ross River-Watson Lake Road. Description of the materials are included on the following pages as well as in the section under "Construction materials".

Description of Potential Aggregate for the Following Grain Size Analyses Curves

Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Areal Extent (Estimated)	Remarks
5	Road cut on south side of Watson Lake-Ross River Road, 12.2 miles east of Horton Creek; 30 feet above road; 2 feet beneath ground surface.	Gravel: sandy, cobbles and boulders to 10 inches; roughly stratified, granitic rocks frequently weathered. <u>Lithology</u> Igneous (granite) - 15% Metamorphic (quartzite, gneiss) - 50% Sedimentary (limestone, sandstone) - 25% Black chert - 10%	None	30 feet (average)	Max. Height - 25 yds. Max. Width - 200 yds. Length - 1000 + yds.	Deposit is in the form of a ridge cut by the road; most satisfactory surfacing material used on road.
6	Road cut on north side of Watson Lake-Ross River Road, 20.5 miles east of Horton Creek; 6 feet above road; 24 inches beneath ground surface.	Sand: medium-grained minor gravel, well graded, loose, stratified, no weathering.	12 inches of yellow silt.	15 + feet	Unlimited	Potential use as blending sand.
7	Road cut on south side of Watson Lake-Ross River Road, 22.3 miles east of Horton Creek; 6 feet above road; 24 inches beneath ground surface.	Sand: fine- to medium-grained; very little silt, no gravel; material is similar but finer than that in sample No. 5.	None	30 + feet	Unlimited	Potential use as a blending sand; material overlies gravel as in sample No. 5.

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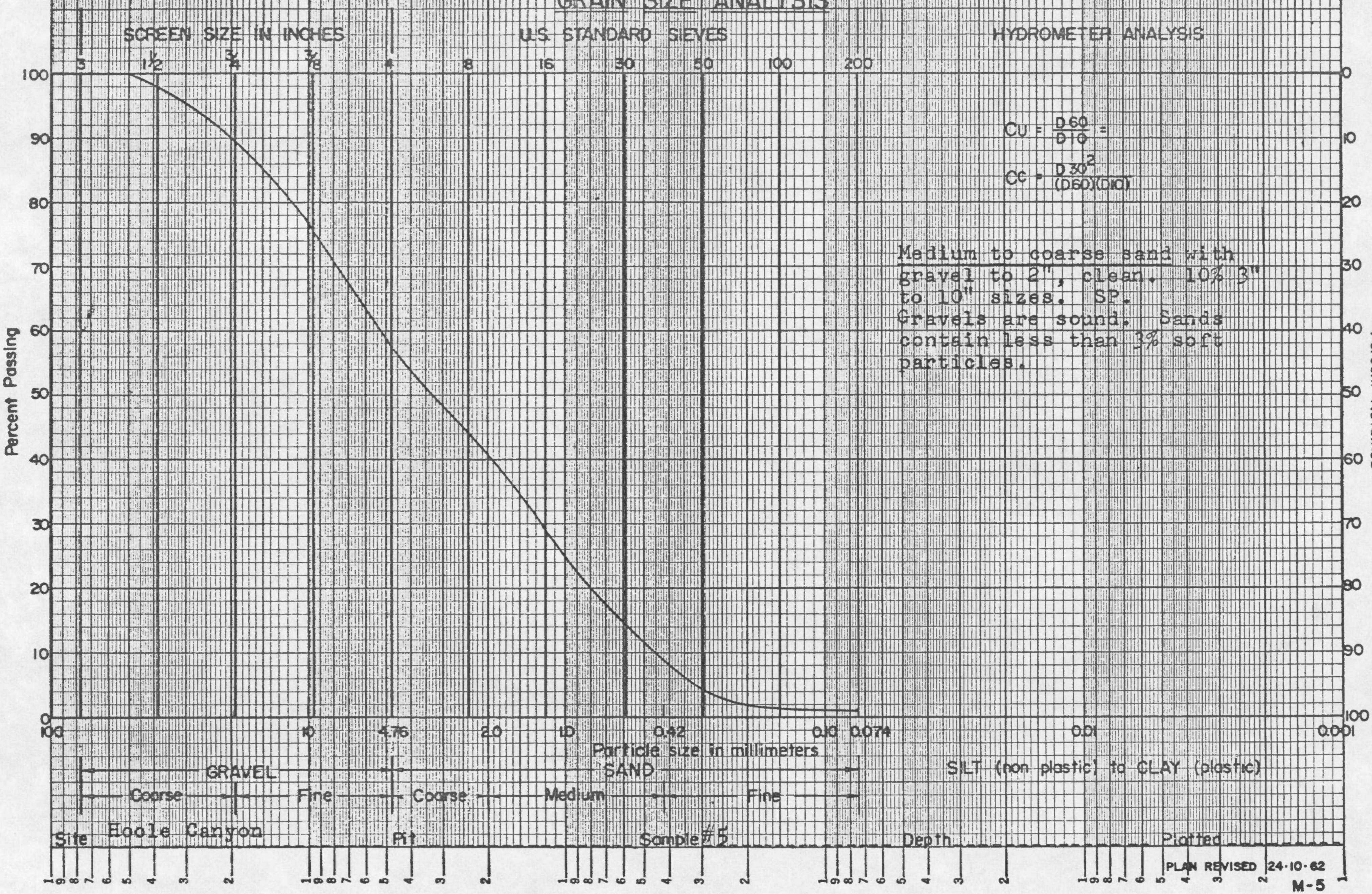
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS



Medium to coarse sand with gravel to 2", clean. 10% 3" to 10" sizes. SP. Gravels are sound. Sands contain less than 3% soft particles.

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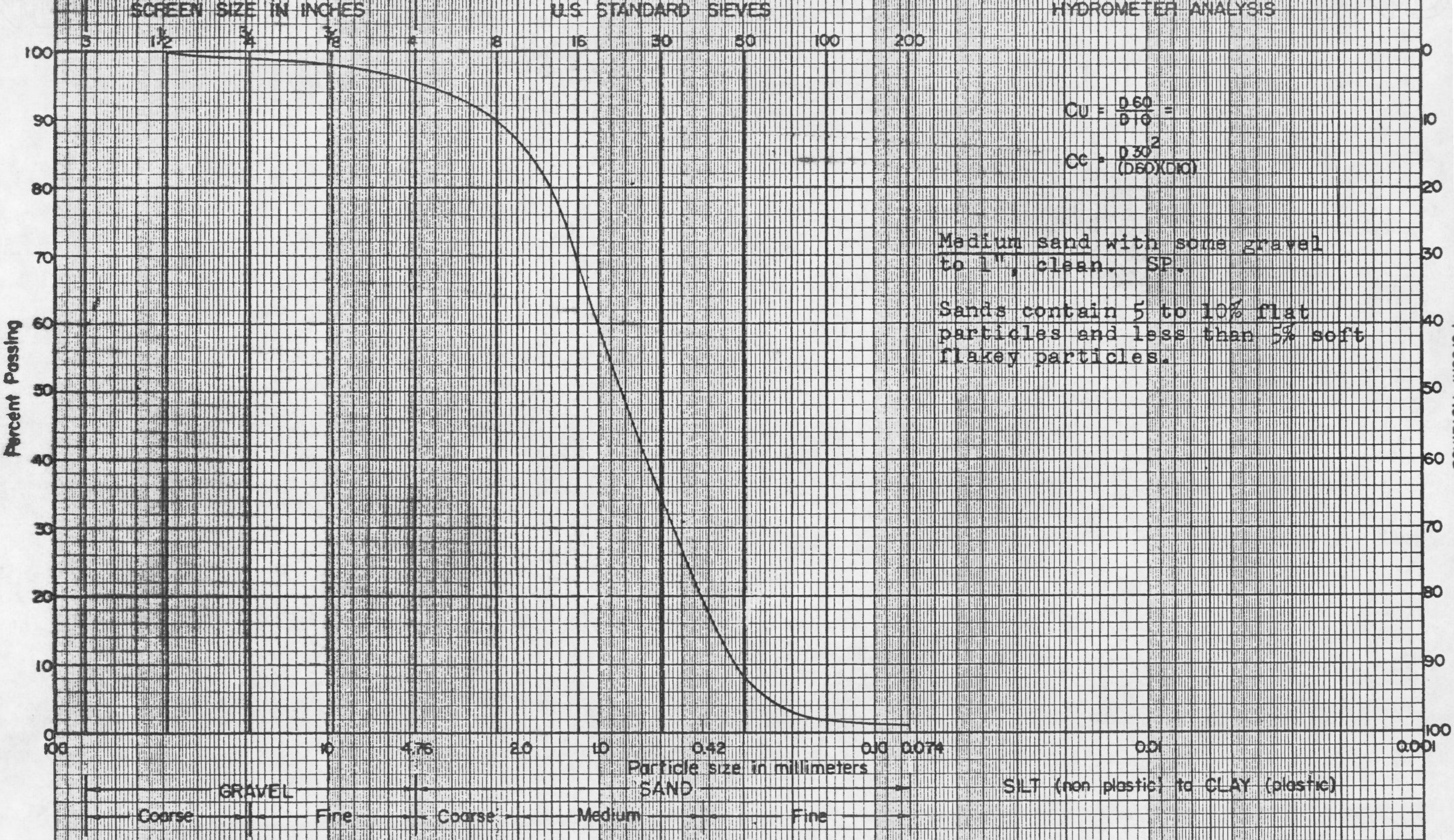
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS



Site Hoole Canyon Pit Sample #6 Depth Plotted

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M-5

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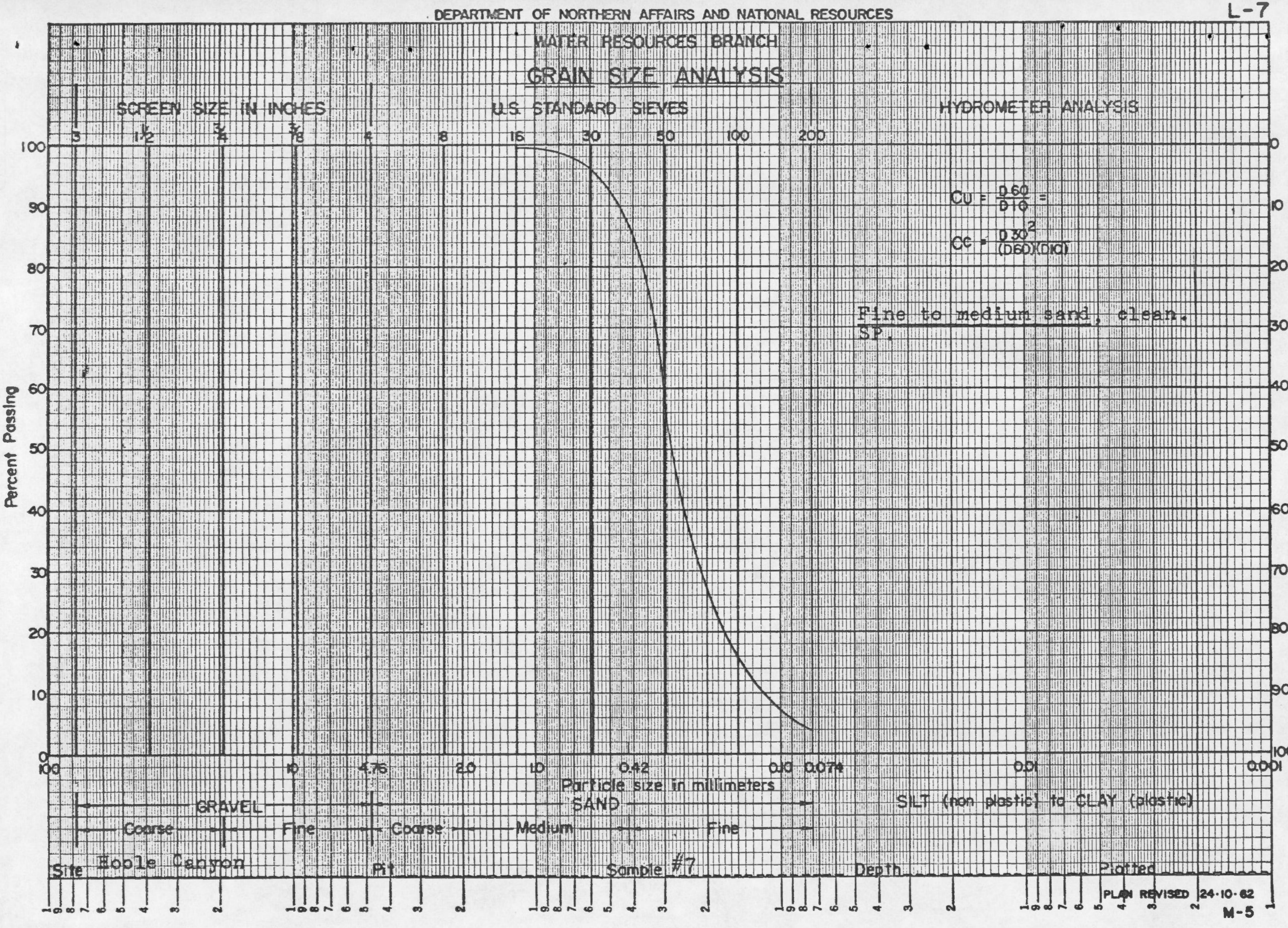
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WATER RESOURCES BRANCH
GRAIN SIZE ANALYSIS
SCREEN SIZE IN INCHES
U.S. STANDARD SIEVES
HYDROMETER ANALYSIS
3
1½
¾
⅜
4
8
16
30
50
100
200
Cu = D60 / D10 =
Cc = D30² / (D60)(D10)
Fine to medium sand, clean.
SP.
Percent Passing
Percent Retained
100
90
80
70
60
50
40
30
20
10
0
100
10
4.76
2.0
1.0
0.42
0.10
0.074
0.01
0.001
Particle size in millimeters
GRAVEL
SAND
SILT (non plastic) to CLAY (plastic)
Coarse
Fine
Coarse
Medium
Fine
Site Hoole Canyon
Pit
Sample #7
Depth
Plotted
PLAN REVISED 24-10-62
M-5
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Description of Potential Aggregate for the Following Grain Size Analyses Curves

Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Areal Extent (Estimated)	Remarks
11	Left abutment, Hoole Canyon dam site; at station E-6; 3 feet beneath ground surface.	Gravel: sandy, very little silt, minor weathering; well graded, loose; white, carbonate coating on many of the larger cobbles and boulders.	None	40 + feet	Large	Weathering less than in other parts of dam site area.
18	Borrow pit on south side of Watson Lake-Ross River Road; 36 miles east of Horton Creek; 3 to 4 feet beneath ground surface.	Gravel: sandy, very little silt; well graded, loose, largest cobble is about 6 inches in diameter, no boulders. Lithology Igneous (granite) - 40% Sedimentary (limestone) - 20% Metamorphic (quartzite) - 20% Shale and schist (weathered) - 10% Chert, black - 10%	None	12 feet maximum	Large	Unlimited quantity available; material used extensively as base and surface course material on road.

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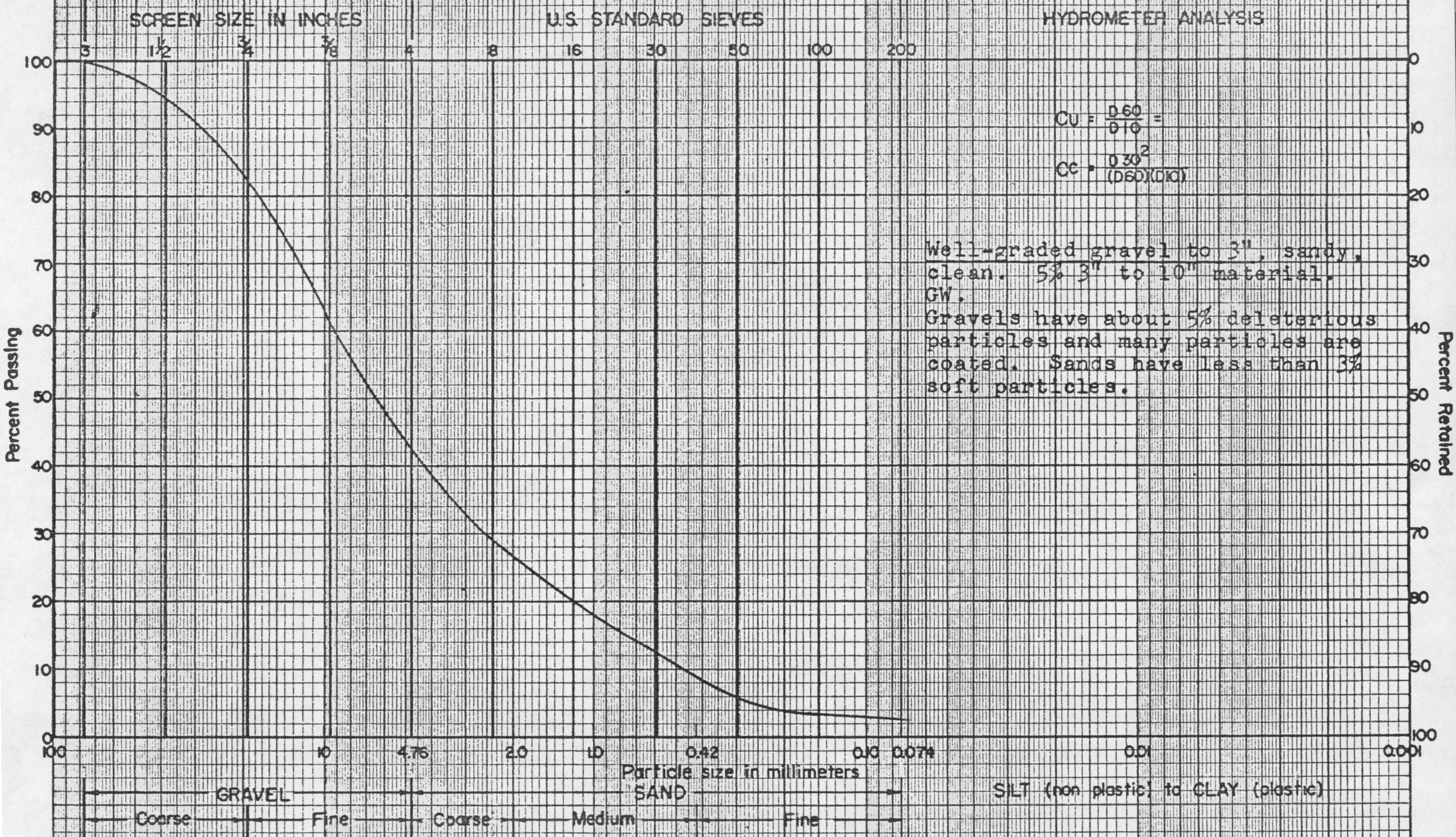
L-7

WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS



$Cu = \frac{D60}{D10} =$

$Cc = \frac{D30^2}{(D60)(D10)}$

Well-graded gravel to 3", sandy, clean. 5% 3" to 10" material. GW.
Gravels have about 5% deleterious particles and many particles are coated. Sands have less than 3% soft particles.

Site Eoole Canyon Pit Sample #11 Depth Plotted

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M-5

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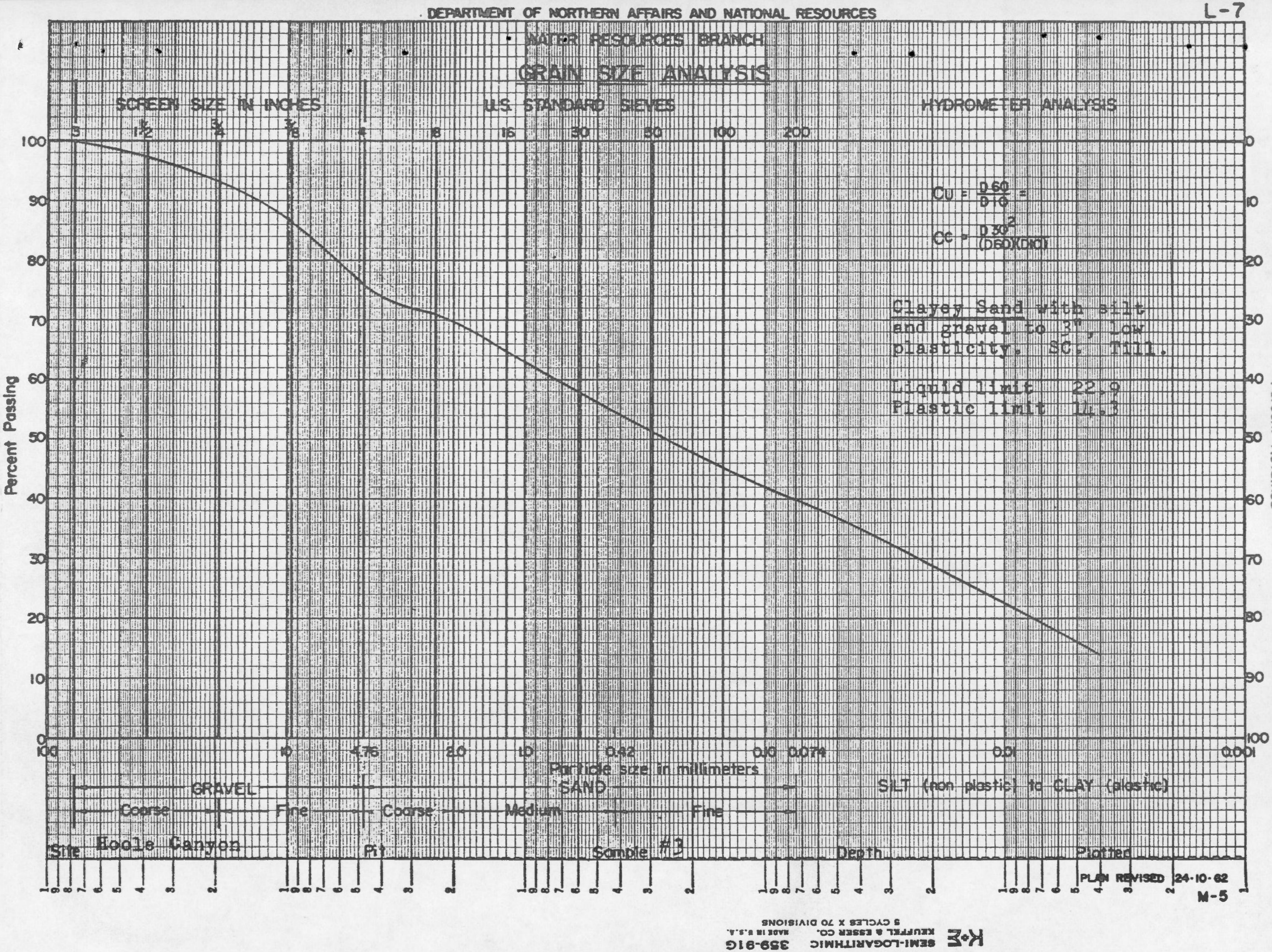
Description of Potential Impervious Material for the Following Grain Size Analyses Curves

Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Areal Extent (Estimated)	Remarks
3	Cut on south side of Watson Lake-Ross River Road, 1.2 miles east of Horton Creek; 15 feet above road; 2 feet beneath ground surface.	Till: Sandy, clayey, minor gravel; dense, grey; rock fragments are chiefly quartzite; maximum size of fragments is about 3 inches.	2 to 3 feet of brown, weathered gravel.	25 feet (average)	Large; a ridge, striking S-20°E across the road consists of the material.	Similar material is exposed at 1.9, 2.4, and 3.4 miles east of Horton Creek.
4	Cut on south side of Watson Lake-Ross River Road, 7.2 miles east of Horton Creek, 15 feet above road, 12 inches beneath ground surface.	Till: gravelly, clayey, silty; very dense, grey; rock fragments similar to those in sample No. 3 except for a larger proportion of black chert.	8 to 10 feet of coarse-grained brown, weathered gravel.	40 + feet	Similar to sample No. 3 with ridge striking at S-8°E.	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WATER RESOURCES BRANCH
GRAIN SIZE ANALYSIS
SCREEN SIZE IN INCHES
U.S. STANDARD SIEVES
HYDROMETER ANALYSIS
Percent Passing
Percent Retained
Cu = D60/D10 =
Cc = D30²/(D60)(D10)
Clayey Sand with silt and gravel to 3", low plasticity. SC. Till.
Liquid limit 22.9
Plastic limit 14.3
Particle size in millimeters
GRAVEL
SAND
SILT (non plastic) to CLAY (plastic)
Coarse
Fine
Coarse
Medium
Fine
Site Hoole Canyon
Pit
Sample #3
Depth
Plotted
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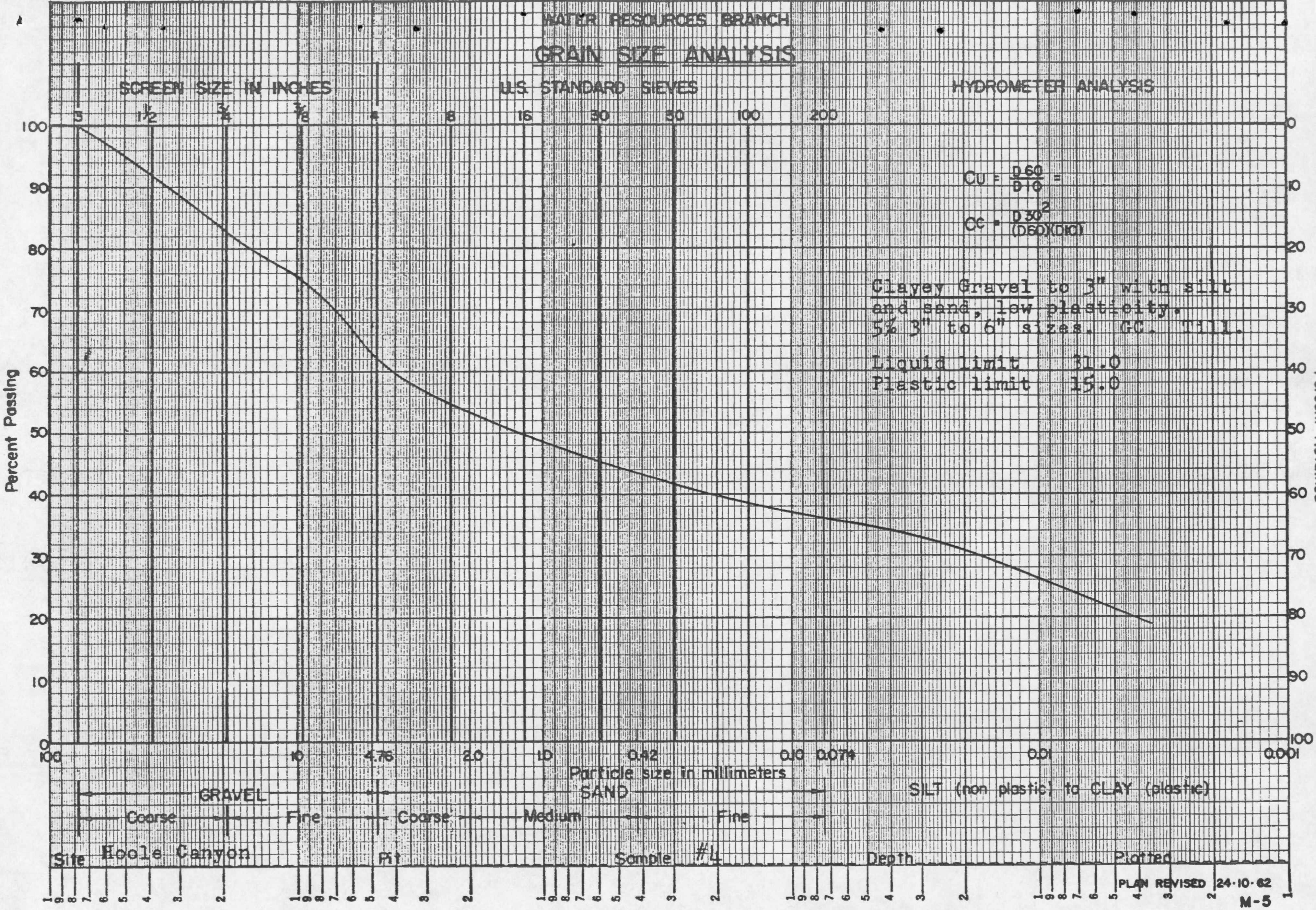

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M-5

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Further Investigations - Conclusions

It should be remembered this report is based upon a preliminary geological investigation designed to furnish the engineer with general geological information regarding the proposed dam site. The data compiled are only sufficiently precise to permit office studies and obtain general cost estimates.

Bedrock in the dam site area consists of serpentinized ultrabasic rocks which have intruded interbedded limestones and quartzites. The sedimentary rocks are believed competent and should provide satisfactory abutment and foundation material. However, the presence of soft, greasy, serpentine which is common in the ultrabasic rocks indicates these rocks might be dangerous in construction.

From the topography the best location for the centre line of the dam would be near the centre of the site area where the canyon is most narrow. However, bedrock exposed in the canyon walls in this locality consists of ultrabasic rocks which in places are highly serpentinized. A more satisfactory site exists in the upstream part of the canyon where limestone is exposed. The water would be diverted along a power canal crossing the open end of the 'U' formed by the river to a power-house situated on the left side of the river in the downstream part of the site area.

Bedrock at the power-house site consists of quartzite cut by several faults. Permeable zones of shattered rock, up to four feet in width, usually occur along the faults. These would have to be grouted.

Overburden exposed in the walls of the canyon consists of coarse-grained, permeable gravel, overlaid in places by a few feet of medium-grained sand. The gravel probably rests upon bedrock. To prevent leakage it would have to be excavated and replaced by impervious material if the elevation of the crest of the proposed dam is higher than bedrock surface exposed in the walls of the canyon (2,550 - 2,600 feet).

Unlimited quantities of glacial materials exist close to the site and consequently there should be no difficulty in obtaining construction materials suitable for an earth dam. There is a lack of fine material in much of the gravel with the result it would have to be processed before being used as aggregate or filter material.

Groundwater will be encountered when the gravel overlying bedrock in the abutments is excavated. Chemical analyses have indicated there are no dissolved minerals in either the groundwater or river water which would be harmful to concrete.

Frozen ground was encountered in a few test pits put down in the site area. It probably occurs throughout most of the area especially along the line of the power canal.

Test borings will be required to determine if bedrock surface slopes upward away from the river in the abutments. They will also be needed along the centre line of the power canal to investigate the permeability of the overburden and the elevation of bedrock surface.

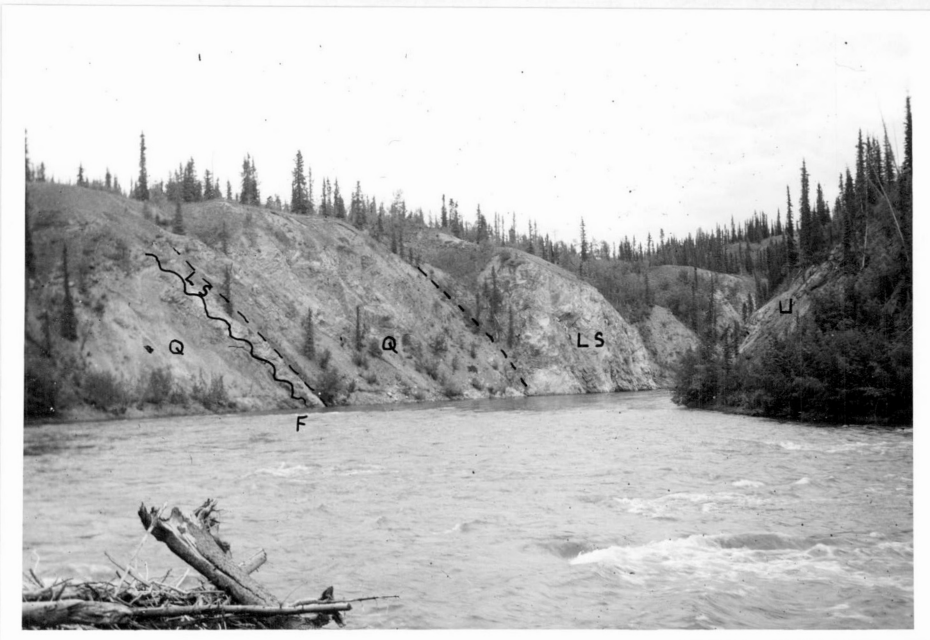


Plate 1

Hoole Canyon looking upstream, proposed centre line of dam is in the most narrow part of the canyon immediately beyond the bend in Pelly River. F - large fault; Q - quartzite; LS - limestone; U - ultrabasic rocks.

G.S.C. 15-4-64

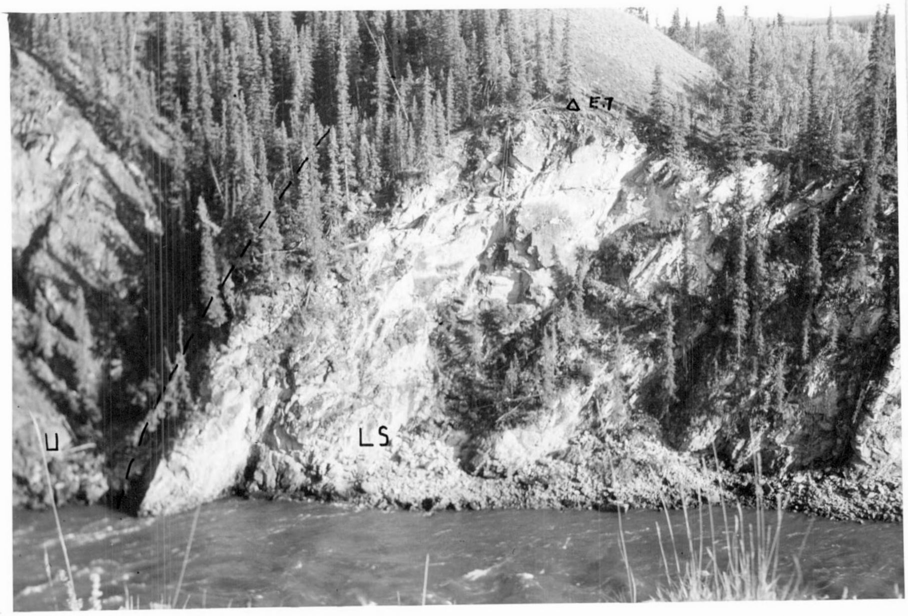


Plate 2

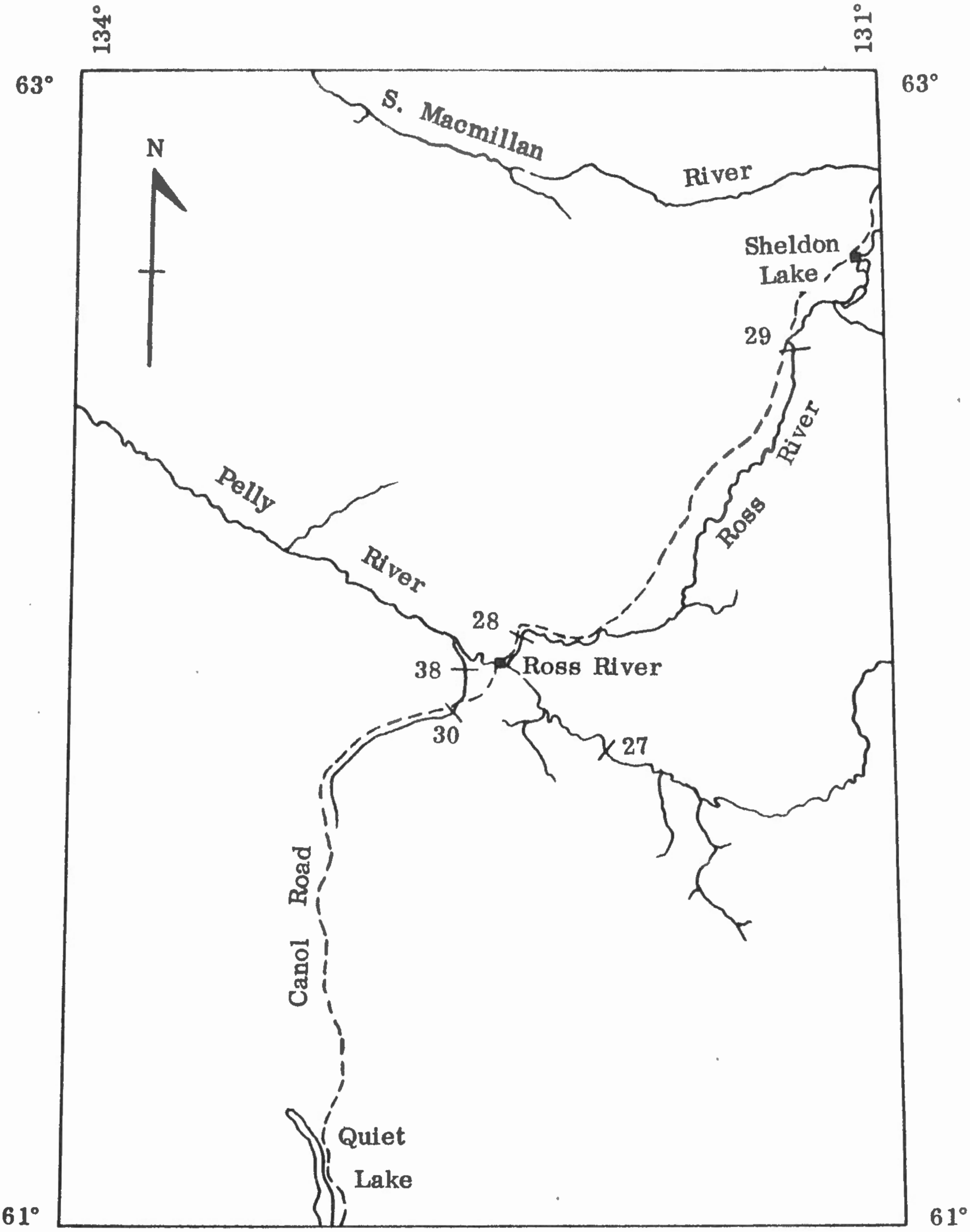
View looking east across the upstream end of Hoole Canyon along the contact of limestone and ultrabasic rocks. This area is believed to be a satisfactory site for the proposed dam. LS - limestone; U - ultrabasic rocks.

G.S.C. 16-4-64

Plate 3

View looking west across the downstream end of Hoole Canyon along the contact of limestone and ultrabasic rocks. Pelly River drops about 3 feet where it crosses the contact. G - gravel, LS - limestone, U - ultrabasic rocks.

G.S.C. 16-2-64



LOCATION OF PROPOSED DAM SITES
YUKON RIVER DRAINAGE BASIN
Scale: 1 inch = 20 miles

Site No.	Name	River
27	Hoole Canyon	Pelly
28	Ross Canyon	Ross
29	Prevost Canyon	Ross
30	Upper Lapie Canyon	Lapie
38	Lower Lapie Canyon	Lapie